INSTITUTO
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The “Company + Farmer” Business Model of Traditional Chinese Medicinal Companies: A Study on the Perspectives of Agricultural Technology Extension and Supply Chain Management

ZHANG Xiangrong

Doctor of Management

Supervisors:
PhD Renato Pereira, Assistant Professor with Habilitation,
ISCTE University Institute of Lisbon
PhD Ma Yongkai, Professor,
University of Electronic Science and Technology of China

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iscte INSTITUTO UNIVERSITÁRIO DE LISBOA	**The "Company + Farmer" Business Model of Traditional Chinese Medicinal Companies: A Study on the Perspectives of Agricultural Technology Extension and Supply Chain Management**	ZHANG Xiangrong

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I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

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Abstract

Currently, the traditional Chinese medicinal materials industry is characterized by an overall supply-demand imbalance favoring supply, yet the raw material supply still fails to meet growing public and industrial demands for green, authentic, and traceable closed-loop circulation, leading to frequent quality issues that make quality improvement an urgent priority. Grounded in the Technology-Organisation-Environment framework, this study investigates from a business model perspective how the "company + farmer" cultivation model affects the quality of traditional Chinese medicinal materials. Using 539 valid questionnaires and applying partial least squares structural equation modeling, this study examines the enhancing effects of technology diffusion and supply chain coordination on quality under this model, along with the moderating role of government support. The findings indicate that technology adoption, technology sharing, supply chain information coordination, and supply chain decision-making coordination all contribute to improving quality. Additionally, government support positively moderates the relationship between supply chain decision-making coordination and quality. However, no evidence was found for government support positively moderating the relationships of technology adoption, technology sharing, or supply chain information coordination with quality. By exploring from a business model perspective how the "company + farmer" model influences farmers' adoption of advanced cultivation technologies to enhance raw material quality, this study enriches understanding of the factors affecting the quality of traditional Chinese medicinal materials.

Keywords: "company + farmer" model; technology adoption; technology sharing; supply chain coordination; government support; quality of traditional Chinese medicinal materials
JEL: O13, Q12

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Resumo

Atualmente, a indústria tradicional chinesa de matérias-primas medicinais apresenta um padrão de desenvolvimento caracterizado por uma oferta superior à procura. No entanto, o fornecimento de matérias-primas medicinais continua a ser insuficiente para satisfazer as crescentes exigências dos consumidores e da indústria em termos de circulação ecológica, autêntica e em circuito fechado, o que leva a frequentes problemas de qualidade. Assim, melhorar a qualidade das matérias-primas medicinais é uma prioridade absoluta. Esta tese utiliza a estrutura Tecnologia-Organização-Ambiente para estudar o impacto do modelo de cultivo "empresa + agricultor" na qualidade das matérias-primas medicinais, numa perspetiva de modelo de negócio. Utilizando um modelo de equações estruturais de mínimos quadrados parciais com 539 questionários válidos, este estudo estudou o papel da difusão de tecnologia e da coordenação da cadeia de abastecimento na melhoria da qualidade das ervas medicinais no modelo "empresa + agricultor" juntamente com o efeito moderador do apoio governamental neste processo. Os resultados indicam que a adoção de tecnologia, a partilha de tecnologia, a coordenação de informações da cadeia de abastecimento e a coordenação de decisões da cadeia de abastecimento contribuem para melhorar a qualidade das ervas medicinais. Além disso, o apoio governamental modera positivamente a correlação positiva entre a coordenação de decisões da cadeia de abastecimento e a qualidade das ervas medicinais. No entanto, não foram encontradas evidências de que o apoio governamental modere positivamente as relações entre a adoção de tecnologia, o compartilhamento de tecnologia, a coordenação de informações da cadeia de abastecimento e a qualidade das ervas medicinais. Este estudo explora, numa perspectiva de modelo de negócio, o mecanismo através do qual o modelo "empresa + agricultor" influencia a adoção de técnicas de gestão de cultivo de alto nível pelos agricultores para melhorar a qualidade das matérias-primas medicinais, enriquecendo assim o conhecimento existente sobre os fatores que afetam a qualidade das ervas medicinais.

Palavras-Chave: Modelo de parceria entre empresas e agricultores; adoção de tecnologia; partilha de tecnologia; coordenação da cadeia de abastecimento; apoio governamental; qualidade das ervas medicinais chinesas

JEL: O13, Q12

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摘　要

当前，中国中药材产业总体呈现供大于求的发展态势。但中药材原料供给尚不能满足群众和行业日益增长的绿色、道地、闭环流通需求，由此带来的中药材质量问题频发。提升中药材质量迫在眉睫。本研究基于“技术-组织-环境”框架，从商业模式的角度考察了“公司+农户”这一中药材种植模式对中药材质量影响。利用收集的 539 份有效问卷，采用偏最小二乘结构方程模型，本研究检验了“公司+农户”模式下技术扩散、供应链协调对中药材质量的提升作用，以及政府支持在这一过程中的调节作用。本文的研究发现，技术采纳、技术共享、供应链信息协同、供应链决策协同能够发挥提高中药材质量的作用。此外，政府支持正向调节了供应链决策协同与中药材质量之间的正相关关系。但是，本研究没有发现政府支持正向调节技术采纳、技术共享和供应链信息协同与中药材质量之间关系的证据。本文从商业模式的角度，探究“公司+农户”模式如何影响种植农户采用高水平种植管理技术以提升中药原材料质量的作用机制，丰富了对中药材质量的影响因素研究。

关键词：“公司+农户”模式；技术采纳；技术共享；供应链协调；政府支持；中药材质量

JEL: O13, Q12

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The successful completion of this study and dissertation first and foremost owes to my supervisor, Professor Renato Pereira of ISCTE-University Institute of Lisbon. Professor Renato has provided me with careful guidance on dissertation topic selection, frame construction, research method selection and even modification of the final draft. Thanks to his sound academic credentials, prudent attitude towards scientific research and international outlook, Professor Renato shows me the way and gives me crucial inspirations and guidance every time there are research bottlenecks. In particular, when I wrote my dissertation in the last year, he provided me with great encouragement and recognition. It is a great honor to learn from Professor Renato, and I would like to express my sincere gratitude to this.

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There is no royal road to a doctorate. During the past five years, in addition to bottlenecks and difficulties in academic research, I experienced the loss of my loved one, got married, and struggled with the constant pressure from my own work and the physical and mental challenges resulting from physical discomfort. It is precisely at these moments that the support and encouragement from my teachers, classmates, junior schoolmates and friends motivated me to keep going. As written in the Preface to the Prince of Teng's Pavilion by Wang Bo, a poet in the Tang Dynasty of China, destitution should toughen up a person, and his sky-high aspiration should not wane. It is my persistent efforts that enable me to finally complete my dissertation. In light of this, I would like to express my special and deep gratitude to my friends in Nanjing and Sheyang, Jiangsu and the friends in the field of traditional Chinese medicine I got to know during my investigation and survey. I'm so thankful to all of you for your invaluable insights

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Now, as I put the final touches on the dissertation, this academic journey starting in Lisbon ends. However, the verses of Camões will still be the footnote for my future journey. “Onde a terra acaba e o mar começa” indicates both the end of this period of study and a new journey of future study. With the knowledge and courage I acquired here, I will continue to explore the new oceans in my academic field.

This study is dedicated to expressing the sincerest gratitude to all of you accompanying, supporting and assisting me throughout this journey!

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这条博士之路并非坦途。在这五年间，我除了遇到学术研究的瓶颈与困难，还经历了亲人离世，步入了婚姻，同时也持续应对着本职工作的压力以及身体不适带来的身心挑战。正是在这些时刻，来自师长、同学、师妹师弟们和朋友们的支持与鼓励，成为了我坚持下去的动力。如中国唐代诗人王勃的《滕王阁序》所写“穷且益坚，不坠青云之志”。就是这份坚持，让我最终没有放弃完成了论文。在此，我要特别向中国江苏南京和射阳的朋友们，以及在调研中认识的中医药领域的朋友们致以深切谢忱。感谢诸位在研究过程中提出的宝贵意见及帮助，为此次学术探索提供了重要指引和实践支持。

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如今论文落笔，这段始于里斯本的学术旅程暂告一段落，但卡蒙斯的诗句仍会是我前行的注脚——“陆止于此”的是这段求学时光的终点，“海始于斯”的是未来研究的新征程。我将带着在这片土地上收获的知识与勇气，继续在学科领域探索“新的海洋”。

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Contents

Chapter 1: Introduction 1
1.1 Research background 1
1.1.1 Significance and applications of traditional Chinese medicine 1
1.1.2 Scale and demand of TCMM 2
1.1.3 Policy context 4
1.2 Research motivation 5
1.2.1 Current status of quality in TCMM 5
1.2.2 Root causes of quality issues in raw medicinal materials 6
1.2.3 Research challenges in TCMM quality 8
1.3 Research questions 8
1.4 Research objectives 9
1.5 Research significance 10
1.5.1 Theoretical significance 10
1.5.2 Practical significance 11
1.6 Research framework 11
Chapter 2: Literature Review 13
2.1 Theoretical foundation 13
2.1.1 Incomplete contract theory 13
2.1.2 Transaction cost theory 14
2.1.3 Agricultural technolgy diffusion theory 16
2.1.4 Farmers' behavior theory 17
2.2 Definition of related concepts 18
2.2.1 "company + farmer" model 18
2.2.2 Companies 20
2.2.3 Farmers 21
2.2.4 Coordination mechanisms 22
2.2.5 TOE theoretical framework 23
2.3 Literature review on contract farming 24
2.3.1 Advantages and disadvantages of contract farming 24
2.3.2 Factors influencing farmers participation in contract farming 27
2.3.3 Governance approaches to promote contract farming development 30
2.4 The diffusion of technology in contract farming 34

2.4.1 Economic consequences of agricultural technology diffusion 34
2.4.2 Factors influencing the diffusion of agricultural technologies 36
2.5 Research related to supply chain coordination 40
2.5.1 Factors influencing supply chain coordination 40
2.5.2 Economic consequences of supply chain coordination 44
2.6 Research related to government support 48
2.6.1 Government support to agricultural production 48
2.6.2 Government support for innovation and entrepreneurship 51
2.6.3 Government support for green production 53
2.6.4 Government support for remanufacturing 56
2.6.5 Government support to consumers 57
Chapter 3: Conceptual Model and Research Hypotheses 61
3.1 Agricultural technology diffusion perspective 62
3.1.1 The impact of technology adoption on the quality of TCMM 63
3.1.2 The impact of technology sharing on the quality of TCMM 65
3.2 Supply chain quality coordination perspective 66
3.2.1 The impact of information coordination on the quality of TCMM 66
3.2.2 The impact of decision-making coordination on the quality of TCMM 67
3.3 Government-supported adjustment perspective 68
3.3.1 Moderating effect of government support on technology adoption for improving TCMM quality 69
3.3.2 Moderating effect of government support on technology sharing for improving TCMM quality 69
3.3.3 Moderating effect of government support on information coordination for improving TCMM quality 70
3.3.4 Moderating effect of government support on decision-making coordination for improving tcmm quality 71
Chapter 4: Research Design 73
4.1 Questionnaire design 73
4.1.1 Purpose of questionnaire design 73
4.1.2 Development of the survey questionnaire 75
4.1.2.1 Overall approach to the survey questionnaire 75
4.1.2.2 Variable measurement 76
4.1.2.3 Assessment and pre-testing 81
4.2 Selection of questionnaire survey samples 84

4.3 Formats of questionnaire surveys 85
4.4 Questionnaire collection 86
4.4.1 Questionnaire collection process 86
4.4.2 Handling of careless responses 86
4.4.2.1 Response time 87
4.4.2.2 Invariance 87
4.4.2.3 Consistency 88
4.4.2.4 Outlier 88
4.5 Research tools and methods 89
4.5.1 Descriptive analysis 89
4.5.2 Reliability analysis method 89
4.5.3 Validity analysis method 90
4.5.4 Structural equation models 91
4.6 Chapter summary 92
Chapter 5: Empirical Analysis 95
5.1 Analysis of descriptive statistics 95
5.1.1 Analysis of socio-demographic characteristics 95
5.1.1.1 Company's socio-demographic characteristics 96
5.1.1.2 Farmer's socio-demographic characteristics 97
5.1.2 Descriptive statistics of the variables 101
5.1.2.1 Descriptive statistics 101
5.1.2.2 Correlation analysis 103
5.2 Common method bias test 103
5.3 Reliability and validity analysis of the measurement model 105
5.3.1 Reliability analysis 105
5.3.2 Validity analysis 106
5.3.2.1 Convergent validity analysis 106
5.3.2.2 Discriminant validity analysis 107
5.4 Collinearity diagnosis 109
5.4.1 Outer model 110
5.4.2 Inner model 110
5.5 Hypothesis testing 111
5.5.1 Overall model fit and explanatory power assessment 111
5.5.2 Results of direct effects testing 113
5.5.3 Results of the moderating effect tests 116

5.5.4 Summary of hypothesis testing results 121
5.6 Analysis of empirical results 122
5.6.1 Differentiation effects of dual paths of technology diffusion 122
5.6.2 Complementary logic of information transparency and decision-making in supply chain coordination 123
5.6.3 Moderating effects of government support: identification of conditional effects 125
5.6.3.1 Reinforcement of government support for decision-making coordination 125
5.6.3.2 Inhibitory effect of government support on technology sharing 125
5.6.3.3 Two scenarios where government support fails to work 126
5.6.3.4 Boundary conditions for the effectiveness of government support 127
Chapter 6: Conclusions and Recommendations 129
6.1 Main research conclusions and recommendations 129
6.1.1 Main research conclusions 129
6.1.2 Managerial implications and suggestions 132
6.2 Contributions and research limitations 136
6.2.1 Theoretical and practical contributions 136
6.2.2 Limitations of this study and future prospects 137
Bibliography 143
Other References 161
Annex: Survey Questionnaire 163

List of Tables

Table 4.1 Reliability test results for variables in the pilot test data..... 83
Table 4.2 Fornell-larcker criterion analysis..... 84
Table 5.1 The basic demographic characteristics of the company-level respondents..... 96
Table 5.2 The basic socio-demographic profile of the farmers..... 97
Table 5.3 Descriptive statistics of variables..... 101
Table 5.4 Correlation analysis of latent variables..... 103
Table 5.5 Harman one-way test results (unrotated factorial solution)..... 104
Table 5.6 Reliability and validity assessment of constructs..... 106
Table 5.7 Cross-loadings analysis..... 107
Table 5.8 Assessment of the fornell-larcker criterion..... 108
Table 5.9 Assessment of the heterotrait-monotrait ratio..... 109
Table 5.10 Assessment of variance inflation factor in the outer model..... 110
Table 5.11 Assessment of variance inflation factor in the inner model..... 110
Table 5.12 PLSpredict algorithm results..... 112
Table 5.13 CVPAT LV summary-PLS-SEM vs. Indicator average (IA)..... 112
Table 5.14 CVPAT LV summary-PLS-SEM vs. Linear model (LM)..... 112
Table 5.15 Results of hypothesis testing..... 113
Table 5.16 Conditional direct effects..... 116
Table 5.17 Summary of hypothesis testing results..... 122

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List of Figures

Figure 1.1 Market size of Chinese TCMM from 2019 to 2023 3
Figure 1.2 Export volume and value of Chinese TCMM from 2020 to 2024 3
Figure 1.3 Number and growth rate of TCM healthcare institutions in China from 2017 to 2023 4
Figure 1.4 Pass rate of randomly inspected TCMM and decoction pieces in China from 2013 to 2022 6
Figure 3.1 Theoretical model for improving the quality of TCMM in the “company + farmer” model of TCMM companies 62
Figure 5.1 Top 10 most frequently cultivated TCMM by respondents 100
Figure 5.2 Evaluation results of the structural model 114
Figure 5.3 Slope chart for GS×TA 117
Figure 5.4 Slope chart for GS×TS 118
Figure 5.5 Slope chart for GS×IC 119
Figure 5.6 Slope chart for GS×DMC 121

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Chapter 1: Introduction

1.1 Research background

1.1.1 Significance and applications of traditional Chinese medicine

Traditional Chinese medicine (TCM) originated in primitive society and has a long history of development in China. To date, Chinese TCM theory has basically taken shape, with a historical accumulation of over 3,000 years. TCM holds a very important position in China and is also a uniquely characteristic traditional medical system. As a tool used by TCM to prevent diseases, treat illnesses, and promote recovery, traditional Chinese medicinal materials (TCMM) play a very important role in the prevention and treatment of major infectious diseases and in safeguarding the health of the general population (Shen et al., 2020).

In China, extensive practice has shown that TCMM play an important role in the prevention and treatment of various diseases. For example, the Miao people in Guizhou Province have developed unique therapies that effectively utilize a variety of plant-based medicines to treat musculoskeletal and connective tissue-related diseases (T. X. Chen et al., 2023). In Henan Province, due to geographical location and climate, local residents have a higher prevalence of atopic dermatitis. Previous studies have found that TCMM such as licorice, Kochia scoparia fruit, angelica, and white atractylodes can be very effective in treating atopic dermatitis (Sun et al., 2025).

In addition, TCMM such as astragalus and forsythia can help prevent epidemic infections (Luo et al., 2020). Especially during the COVID-19 period, numerous studies have shown that TCMM can effectively alleviate flu symptoms, reduce severe cases and mortality, and play a positive role in recovery (Du et al., 2021; S. F. Shi et al., 2021). The effects of TCMM are not only reflected in the prevention and treatment of diseases; some herbs also have the characteristic of “being both medicine and food,” and can be directly used as food and health supplements (M. X. Zhang, 2022).

Using medicinal plants in healthcare is a common practice around the world. For instance, in Central Europe, people have used about 100 medicinal plants for hundreds of years to treat issues with the skin and stomach problems (Dal Cero et al., 2022). However, because of different medical and cultural frameworks, TCM is often referred to as “complementary

medicine" in most Western countries and is not fully accepted in mainstream healthcare. To close this gap, China is still doing research to make TCM more well-known and effective as a treatment (A. X. Lin et al., 2018). Artemisinin, a compound derived from TCMM, is a notable success. Since 2001, the World Health Organization has recommended artemisinin-based combination therapies as the first-line treatment for malaria. This recommendation was made because Tu Youyou's team discovered it (Mutabingwa, 2005).

TCM is quickly becoming increasingly prevalent around the world. By 2023, TCM had made its way to 196 countries and regions. The Chinese government had also signed formal coordination agreements on TCM with more than 40 countries. This growing acceptance is in line with a larger trend around the world. About 85% of the world's population relies on medicinal plants for their main health care (Adhikari et al., 2021).

1.1.2 Scale and demand of TCMM

There are an extensive number of TCMM resources in China. The Fourth National Survey of TCM Resources reported 18,817 different species. This includes 15,321 types of medicinal plants, 3,151 of which have only been identified in China. The survey also found 196 new species. Initial analysis indicates that around 60% of these newly discovered plants may have medicinal potential (L. Q. Huang et al., 2024).

There are about 600 different types of TCMM that are commonly used in China at the moment. More than 300 of these types are currently being cultivating. The National Plan for the Development of Authentic Medicinal Herb Production Bases (2018–2025*)* indicates that China's medicinal herb growing area had grown to over 33 million mu (about 2.2 million hectares) by 2018. Data from Beijing Yanjing Bizhi Information Consulting shows that by 2024, the TCMM cultivation area had increased to 56.9 million mu (about 3.8 million hectares). By 2030, the area for growing will likely be more than 60 million mu (about 4 million hectares), and "geo-authentic herbs"—herbs grown in specific, traditional areas for the best quality—are expected to make up 70% of the total. In consequence of this, unique production areas have been set up for these natural herbs, like the Four Huai Herbs, Zhejiang's Eight Treasures, Sichuan Herbs, Guan Herbs, and Qin Herbs.

The demand for TCMM on the market has been steadily rising over the past few years. In particular, the demand for TCMM in China has been steadily increasing since 2020. Figure 1.1 shows the size of the TCMM market from 2019 to 2023. The Zhongyan Puhua Industry Institute's research report 2024-2029 China Traditional Chinese Medicine Industry In-Depth

Analysis and Development Planning Consulting Report indicates that the TCMM market was estimated at 477.2 billion yuan in 2023.

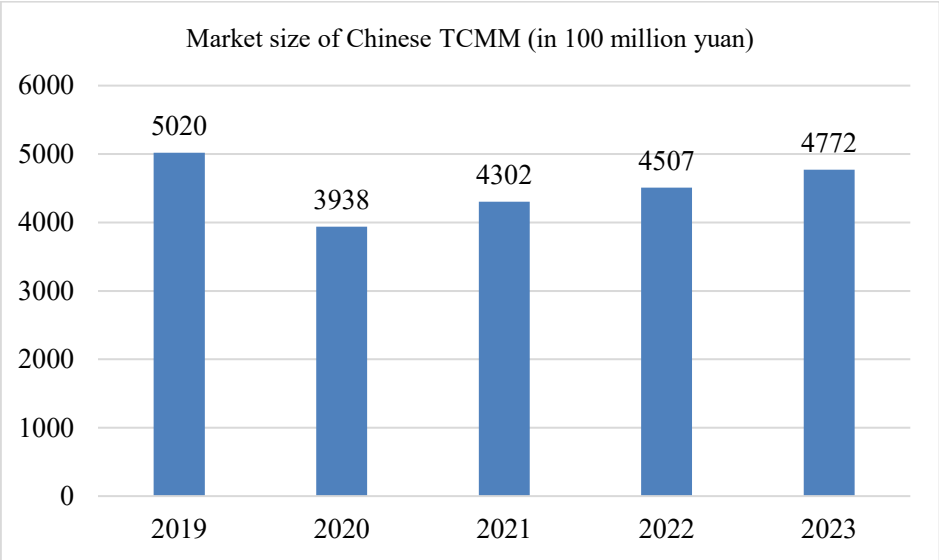


Figure 1.1 Market size of Chinese TCMM from 2019 to 2023

Source: National bureau of statistics of China (2024)

China exported 125,971 tonnes of herbal medicines in 2021, bringing in US$962.93 million in sales. The amount of TCMM that was exported in 2022 was 134,794 tonnes, which was the highest level in the previous five years. In general, TCMM exports are going through a period of change at the present time. Figure 1.2 displays how TCMM's exports change from 2020 to 2024.

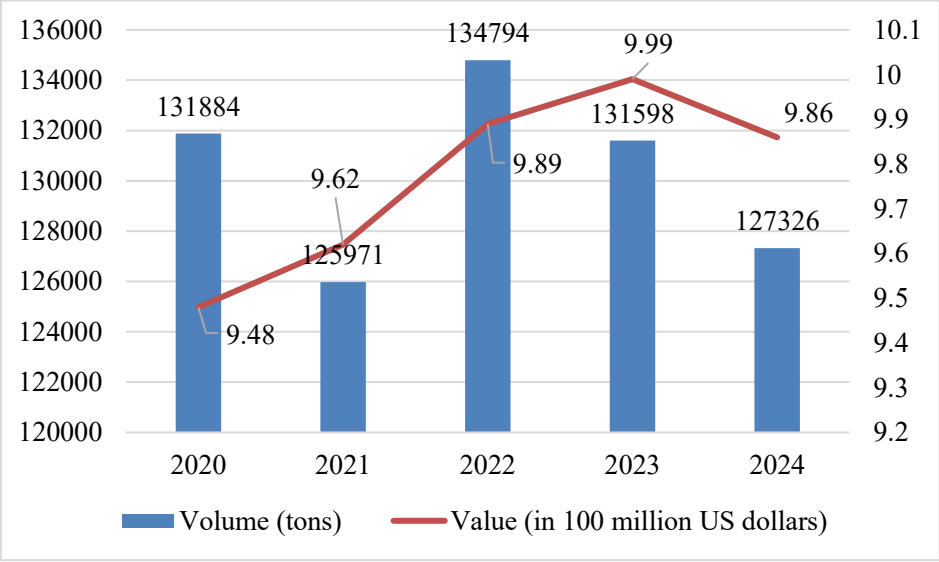


Figure 1.2 Export volume and value of Chinese TCMM from 2020 to 2024

Source: National Bureau of Statistics of China (2025)

The supply of TCM services has kept growing consistently. Figure 1.3 shows how many TCM healthcare facilities there are in China and how fast they are increasing. The National Health Commission's Statistical Bulletin on China's Health Development states that by 2023,

China had a total of 1,070,785 healthcare institutions. The number of TCM healthcare institutions grew by 15.20% annually, reaching 92,531. Furthermore, all kinds of public medical institutions have built up TCM diagnosis and treatment departments. The number of beds in TCM medical facilities also grew quite significantly in terms of capacity. There were 1,731,946 beds in TCM hospitals by the end of 2023. The number of beds in these facilities also grew at a rate of 9.10% in 2023, which is in line with the trend of more institutions being established. Also, TCM services are now widely available in communities. More than 90% of community health service centres, township health centres, and community health service stations across the country can now provide TCM services(Y. X. Zhang, 2022).

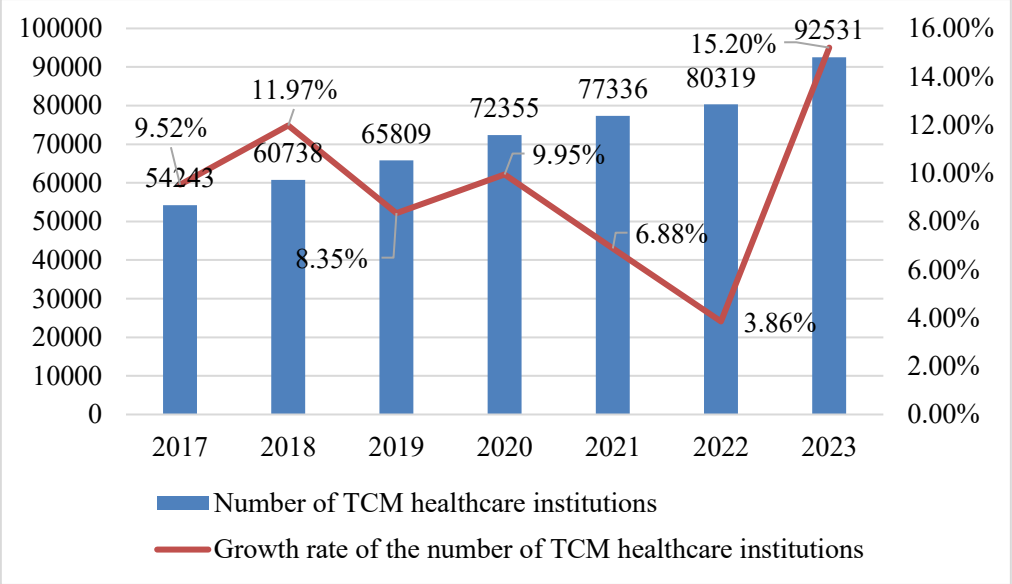


Figure 1.3 Number and growth rate of TCM healthcare institutions in China from 2017 to 2023

Source: National bureau of statistics of China (2024)

1.1.3 Policy context

The Chinese government has put in place a number of policies to assist the TCMM industry prosper in a high-quality manner. For example, the State Administration of Traditional Chinese Medicine put out the Interim Measures for the Administration of Traditional Chinese Medicine Standardisation Projects in 2006 to set rules for these kinds of projects. In 2012, the Medium- and Long-Term Development Plan for Traditional Chinese Medicine Standardisation (2011–2020) was released out. This plan was the main guide for standardisation efforts.

The State Council put out the Strategic Development Plan for Traditional Chinese Medicine (2016–2030) in 2016. This plan laid out the course and goals for TCMM development for the next fifteen years. The Law of the People's Republic of China on Traditional Chinese Medicine, which was passed in 2017, was a big step forward in the law. It officially recognised the

importance of TCMM.

The Opinions of the General Office of the State Council on Enhancing the Quality of Traditional Chinese Medicines and Promoting High-Quality Development of the Traditional Chinese Medicine Industry came out in 2025. This policy stressed a few important goals: speeding up the improvement of TCMM quality, encouraging the TCMM industry's high-quality growth, and making sure that commonly used TCMM is grown in a standardised way and is always available.

The implementation of this series of policies and regulations in China has served a dual purpose. Not only has it protected the long-term growth of the TCMM industry and the larger field of TCM, but it has also gradually set higher standards for industry growth, stricter quality standards, and more strict oversight.

1.2 Research motivation

1.2.1 Current status of quality in TCMM

Among TCMM, plant-based medicinal materials account for more than 80% of the total, with plants unique to China making up 17%. Therefore, this research focuses on plant-based medicinal materials.

In China, the main supply chain for TCMM starts with farmers growing raw materials and ends with TCMM companies turning those materials into finished products. Over the past 20 years, national policies that support TCMM development have led to rapid growth in this part of agriculture. Good Agricultural Practices (GAP) now guide modern agriculture, which is different from traditional farming methods. There has also been a lot of progress in moving from materials that are harvested from the wild to those that are grown and raised. But even though things have gotten better, the demand for TCMM has been steadily rising, which has led to more quality-related problems.

Quality assessment and monitoring of pharmaceuticals in China from 2013 to 2022 showed that the overall compliance rate for TCMM and their corresponding decoction pieces was steadily improving. Figure 1.4 demonstrates that the compliance rate went up from 64% to more than 90% during this time, suggesting that the quality got a lot better. By 2022, the compliance rate was over 98% (P. Zhang et al., 2023). But even with this progress, the rate of non-compliance for TCMM and decoction pieces is still greater than for other pharmaceutical products. For instance, in 2019, 114 pharmaceutical companies lost their Good Manufacturing

Practice (GMP) certificates. The World Health Organisation defines GMP as rules that govern the production and quality control of food, drugs, and medical devices. Sixty of the companies that had their certificates taken away that year were TCMM decoction piece manufacturers, which is 52.6% of the total. This action got rid of businesses that made crude and low-quality TCMM decoction pieces from the market.

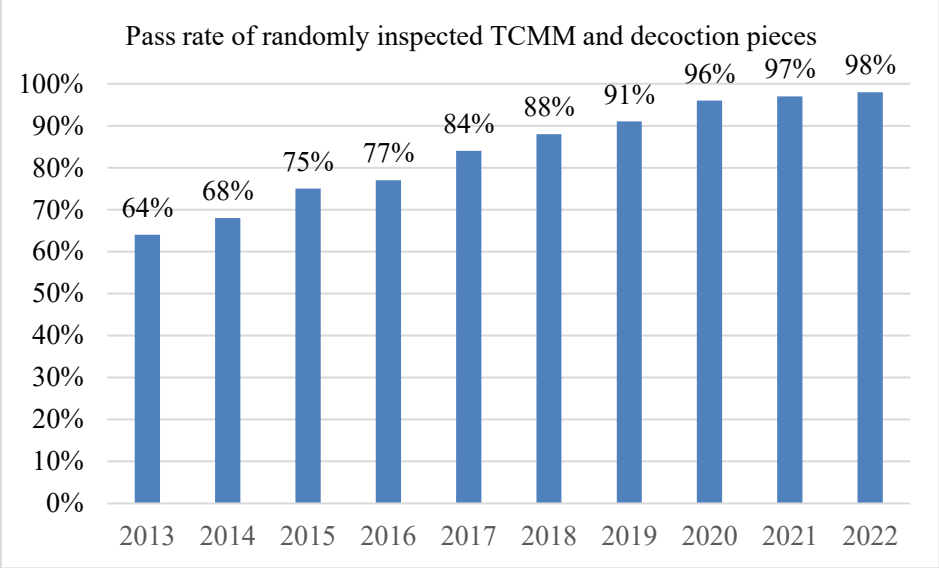


Figure 1.4 Pass rate of randomly inspected TCMM and decoction pieces in China from 2013 to 2022

Source: National drug sampling inspection annual report (2023)

Overall, the growth of the TCMM industry has made some of the problems with inconsistent quality less serious, but there are still major problems. These include practices such as dyeing to make things heavier, having too many heavy metals and pesticides, and replacing one species with another, which are still big problems (P. Zhang et al., 2023).

1.2.2 Root causes of quality issues in raw medicinal materials

Problems with the quality of TCMM raw materials make herbal medicines less effective and safe, hurt the reputation of TCM, and make it harder for TCM to grow in a sustainable way. There are three main reasons why these quality problems exist.

First, there is a shortage of TCMM resources, which cannot meet the growing demand. With ongoing environmental changes and rising global temperatures, the habitats of many precious TCMM herbs have been destroyed. This has led to some medicinal herbs becoming endangered, facing the risk of a sharp decline in numbers. At present, more than 280 TCMM herbs have been identified as endangered species (X. B. Zhang et al., 2014). However, the high profit margins of these rare herbs have further intensified overharvesting and excessive collection. In addition, in China, the legal system for protecting endangered TCMM herbs is

not well-developed, which further exacerbates the unreasonable use of these medicinal herbs. Some sellers, in pursuit of profit, process raw TCMM materials through adulteration, dyeing inferior herbs, and excessive sulfur fumigation, which damages the quality of the medicinal materials.

Secondly, the production and management of TCMM are relatively rough, specifically manifested in the following ways: the germplasm of propagation materials is mixed, varieties are degraded, and quality varies; blind introduction of species leads to a decline in the authenticity of medicinal materials; production and processing of TCMM are not standardized, with extensive use of chemical fertilizers, pesticides, and other additives during cultivation, resulting in widespread issues such as heavy metal and pesticide residues; premature harvesting and processing are also common.

For example, a research team composed of personnel from the Shanghai Institute for Food and Drug Control and the National Medical Products Administration has long been focusing on the issue of pesticide residues in TCMM. In high-throughput sequencing pesticide screening of 4,670 batches, covering more than 200 different medicinal parts of TCMM, they found that approximately 43.5% of the herbal materials and their slices contained pesticide residues. Moreover, they discovered that the detected samples contained as many as 246 different types of pesticides (Miao et al., 2022). This highlights the serious problem of excessive use and the wide variety of pesticides in the cultivation of TCMM.

Finally, there are difficulties in regulating the quality of TCMM. The TCMM industry chain is relatively long, including stages such as seed selection, seedling cultivation, planting, harvesting, processing, preparation, distribution, and sales. Each of these stages can affect the quality of the medicinal materials. Quality regulation of TCMM can be traced back to the Western Zhou period. For a considerable period afterward, quality regulation mainly relied on sensory evaluations such as appearance, color, and smell. After 1953, quality testing institutions for TCMM were established, marking the official beginning of modern regulation in China. With the development of technology, methods for regulating the quality of TCMM have shifted to spectral and chromatographic techniques. Indeed, the methods for regulating the quality of TCMM have continuously developed; however, the production and circulation of these materials have not yet formed a full-process traceability system. This increases the difficulty of implementing comprehensive quality regulation throughout the entire process.

1.2.3 Research challenges in TCMM quality

At the moment, China's TCMM industry may show a general trend of supply exceeding demand, but there is still a major shortfall because the supply of high-quality raw materials does not meet the growing demand for products that are green, authentic, and sustainably sourced. This difference is due to the fact that these materials have unique properties that make it impossible to use a single standard to accurately measure their quality. Because of this, TCMM companies have a hard time making sure that the raw materials they purchase are environmentally friendly. To meet current procurement standards that may not accurately reflect quality and to lower their own financial risks, farmers are often encouraged to use non-sustainable farming methods to make the greatest profit possible. This leads to inconsistent quality across the TCMM market. On June 19, 2021, China set up the National Alliance for Standardisation and Quality Assessment of Chinese Herbal Medicines to try to fix these problems at their source.

Scholars have long been very concerned about making TCMM better. The current literature predominantly examines strategies for developing ecologically sustainable, high-quality TCMM. These studies concentrate on technical aspects, including external environments (Rana et al., 2017), agricultural practices (C. Li et al., 2021), germplasm resources (Morris & Wang, 2018), and field management strategies (H. Liu et al., 2021; Lv et al., 2024; Müller et al., 2019). Nonetheless, there is a deficiency of research investigating the impact of business models on farmers' implementation of environmentally sustainable agricultural practices. This study is driven by the existing research gap and the pressing necessity to enhance the quality of medicinal herbs. Consequently, we examine the function of China's "company + farmer" cultivation model in improving the quality of TCMM raw materials.

1.3 Research questions

The main question that this research tries to answer is how to improve the quality of TCMM's raw materials. This study examines the efficacy of the "company + farmer" cultivation model in resolving these quality issues in alignment with China's national context.

The quality of TCMM is influenced by the quality of seeds, field cultivation techniques, methods of harvesting, storage methods, processing methods, and decoction techniques. However, the seeds for TCMM are mainly provided by companies, making their quality controllable. As for harvesting, storage, processing, and decoction stages, enterprises can also play a leading role in controlling the quality of raw medicinal materials. This study focuses on

the impact of the "company + farmer" planting model on improving the quality of raw medicinal materials for farmers. Since the cultivation stage of TCMM is led by farmers, this study concentrates on how the "company + farmer" planting model can play a role in improving the quality of raw medicinal materials during the farmers' field cultivation stage.

The cultivation methods and techniques chosen by TCMM farmers are important factors affecting the quality of medicinal herbs. Advanced cultivation techniques can help improve the quality of TCMM. Meanwhile, supply chain coordination can alleviate some quality issues caused by the overly long TCMM industry chain. This study will conduct interviews with TCMM farmers and executives of TCMM companies, and carry out a questionnaire survey to identify the factors affecting the quality of TCMM grown by farmers. Our aim is to understand farmers' technical capabilities in herb cultivation, the costs of growing TCMM, their attitudes toward adopting new techniques, and their perceptions of cultivation risks. Additionally, this research will design questionnaire items related to market demand for TCMM, quality assessment of TCMM, and company pricing arrangements for purchasing TCM herbs in order to comprehensively grasp the factors that may influence the quality of TCMM.

The successful functioning of the "company + farmer" model relies not only on the coordination between TCMM companies and farmers but also on external influences. This study examines external influences on the collaborative development of companies and farmers from a governmental perspective, highlighting the essential role of government support for boosting TCMM quality.

1.4 Research objectives

There has been quite of progress in making TCMM more modern and industrialised, and consumption is still rising in China. A global trend of "returning to nature" has led to the development of large-scale markets for TCMM in the European Union. This presents a huge opportunity for trade that has not yet been taken advantage of. But the demand for these plants is growing, while the supply of wild medicinal plants is shrinking at an alarming rate of 30% per year and can not keep up with market needs(Z. Y. Yan, 2012). As a result, farming has become the most common way to grow TCMM in China, making the country a major producer of TCMM around the world. More importantly, this change to intensive farming has brought its own problems. For example, using too many pesticides and fertilisers and not following scientific farming methods have caused quality problems, like unstable levels of active ingredients and heavy metal levels that are higher than what the law allows.

This study tests the potential of the "company + farmer" cultivation model, tailored to China's national context, to improve the quality of TCMM raw materials. The results are meant to help make policy suggestions for the industry's high-quality growth, which will help meet the demand for high-quality materials and allow TCMM to better serve public health. This research has specific goals that are meant to help reach these goals.

(1) To examine, from a technology diffusion standpoint, how advancements in cultivation methods within the "company + farmer" framework elevate the quality of TCMM.

(2) To examine, from a supply chain perspective, how the synergistic effects produced by the "company + farmer" model enhance the quality of TCMM.

(3) To analyse, from a governmental standpoint, the beneficial moderating effect of government support in improving the quality of TCMM raw materials within the "company + farmer" cultivation model.

1.5 Research significance

1.5.1 Theoretical significance

Utilising the Technology-Organization-Environment (TOE) framework, this study develops a model to investigate the determinants affecting TCMM quality within the "company + farmer" cultivation system. This study systematically explains the interdependence of agricultural technology, supply chain quality coordination, and government support in achieving sustainable quality improvement of TCMM raw materials under the "company + farmer" model. Focusing on the promoting effects that the "company + farmer" medicinal herb cultivation model has on farmers' field cultivation processes, this work to some extent enriches the research on the consequences of the "company + farmer" medicinal herb cultivation model.

Currently, quality issues with TCMM seriously hinder the healthy development of the industry. To address this problem, many scholars have explored, from the perspectives of the external environment, field cultivation management techniques, and processing and storage, under what conditions the active ingredient content of TCMM can be increased, related pests and diseases reduced, and ultimately, the materials can achieve the best effect in treating diseases. However, in China, farmers surviving under a small-scale agricultural economy are generally limited by their knowledge. In fact, they often lack systematic knowledge regarding field cultivation management. This study explores, from the perspective of business models, how the "company + farmer" model affects the mechanism by which farmers adopt high-level

cultivation management techniques to improve the quality of TCMM, thereby enriching research on the factors influencing the quality of these materials.

1.5.2 Practical significance

Both the Chinese and global markets for TCMM have a huge demand for high-quality raw materials. As an important supplier of TCMM, China's supply quality is crucial. Especially for TCMM companies, they need higher-quality raw materials to produce high-quality medicines and meet the huge market demand. This research studies how China's unique "company + farmer" model can help coordinate the relationship between TCMM companies and medicinal material farmers, jointly promoting the improvement of raw material quality. The research conclusions of this work provide feasible suggestions for improving the quality of TCMM raw materials.

The "company + farmer" model is an integral part of achieving high-quality development in China's TCMM industry. Under this business model, companies can share more standardized field management and cultivation techniques with farmers. This can gradually transition TCMM cultivation methods from extensive, unmanaged practices to eco-friendly approaches, reducing harm to the natural environment. In other words, the "company + farmer" TCMM cultivation model can help disseminate green cultivation technologies from companies to farmers, promoting more scientific and rational use of land and other natural resources, and subtly advancing the high-quality development of China's TCMM industry.

1.6 Research framework

This study focuses on exploring the impact mechanism of the "company + farmer" TCMM planting model on improving the quality of raw materials at the farmer's field stage, as well as the regulatory role of government support in this process.

First, this research provides an overview of the state of TCMM industry by introducing the importance of TCM, the scale of China's TCMM industry, and relevant policy support.

Second, this study systematically reviews the relevant literature on contract farming, technology diffusion, supply chain coordination, and government support, provides a detailed analysis of the current state of research, and on this basis, proposes research hypotheses.

Third, through designing relevant questionnaires and scales, conducting field interviews, and other methods, we collect the views of companies and farmers on the quality improvement effects brought by the "company + farmer" TCMM planting model, and measure technology

adoption, technology sharing, information coordination, decision-making coordination, government support, and the quality of raw materials for TCMM.

Fourth, using the data collected from the questionnaires, this study employs structural equation modeling to verify the role and mechanism of the “company + farmer” TCMM planting model in improving the quality of raw materials at the field cultivation stage, and to examine the moderating effect of government support in this process.

Fifth, based on the research conclusions, this work intends to formulate relevant recommendations for improving the quality of TCMM at the field cultivation stage, providing valuable insights for the sustainable and high-quality development of the TCMM planting industry from the perspective of business models.

Chapter 2: Literature Review

2.1 Theoretical foundation

2.1.1 Incomplete contract theory

A contract is a formal agreement or promise made by two or more people that spells out what each person has to do and what they can do. The Civil Code of the People's Republic of China defines a contract as an agreement through which civil subjects establish, modify, or terminate civil legal relationships. According to the completeness of the contract, contracts can be divided into complete contracts and incomplete contracts.

A complete contract means that both parties who signed it can fully and accurately see every potential event that could happen while the agreement is in effect. They also proactively make arrangements that work for both parties in case these situations happen and make sure that the contract can be properly carried out and enforced.

An incomplete contract is a type of agreement in which the parties involved in the contract fail to fully predict all of the possible situations that could happen during the contract's term because of things like missing information and transaction costs. Alternatively, the costs associated with the contracting process may be excessively high, hindering the parties' ability to create a comprehensive and detailed contract in advance and guarantee its effective enforcement. In these situations, the parties must renegotiate after the fact about what actually happened and what the results were during the contract period. The main idea behind incomplete contract theory is to employ rational property rights arrangements to lower the costs of possible "hold-up" problems, which is how to achieve the goal of second-best efficiency.

Coase (1937) was the first to explain the reasons for the existence of firms from the perspective of incomplete contracts, pointing out that firms can replace the market due to the presence of costs in market transactions. By comparing market transaction costs with organizational costs, he argued that the boundaries of the firm would continue to expand until the cost of organizing transactions internally is no less than the cost of market transactions or the cost of achieving the same outcome through transactions with other firms. The comparison between organizational costs and market transaction costs indicates that the boundaries of the firm depend on the degree of completeness of market contracts. The more incomplete the

market contracts, the higher the market transaction costs, and the more likely firms are to replace the market.

After years of development, the theory of incomplete contracts has split into two main groups. The first is the transaction cost economics school, which Williamson is a part of. This school contends that in scenarios involving incomplete contracts, governance frameworks ought to be chosen according to informational conditions and transaction attributes to reduce both ex ante and ex post transaction costs (Williamson, 1979). The second is the property rights school, which includes Hart, Grossman, and Moore. This school supports the logical distribution of residual control rights in the ex ante phase to boost incentives for investments that are specific to a relationship (Grossman & Hart, 1986).

2.1.2 Transaction cost theory

Transaction costs are a fundamental topic in economic research (Williamson, 1979). Coase first used the term “transaction cost” in his significant work “The Nature of the Firm.” He stated that transactions do not take place in a frictionless economic environment, indicating that every real-world transaction entail cost (Coase, 1937). He characterised transaction costs as the diverse expenditures incurred by parties involved in transactions to acquire precise and dependable market information during market operations. The initial focus of transaction cost theory was the enterprise, as his research primarily concentrated on firms. Following that, a lot of researchers built on the idea of transaction costs and said that they should be measured based on three main factors: asset specificity, transaction frequency, and transaction uncertainty.

From a definitional standpoint, North (1987) defined transaction costs as expenditures incurred both prior to and subsequent to the formation and execution of contracts, encompassing all expenses associated with political and economic entities that facilitate economic agents’ engagement in business activities. Eggertsson (1990) contended that significant transaction costs in economic activities typically stem from endeavours to optimise resource allocation and generate additional value in compliance with established regulations.

In contract-based contract farming, transaction costs typically show up as institutional costs for searching for and matching producers and buyers, negotiating price and quality terms, overseeing and rewarding contract execution, and settling disputes and sharing risks. For example, earlier studies have shown that processors in the Dutch pork market need to grade the quality of agricultural products to set prices. This makes sure that the prices are fair and that processors get high-quality agricultural products (Boger, 2001). Transaction costs can be

affected by market risks in livestock farming, farmers' specialised investments, and quality costs (United States Department of Agriculture, 2002).

Transaction costs are closely related to how well an organisation does its assigned task, so it is essential to keep an eye on these costs. A lot of research has been done on how to handle transaction costs in farming. In China's agricultural sector, which is mostly made up of smallholder farmers, high transaction costs for trading agricultural goods have made it challenging for the sector to grow in a healthy way.

The Rural Vitalisation Strategy was put into place in China in 2017. The "Internet Plus Agriculture" policy has brought e-commerce funds into rural areas, which has lowered the costs of agricultural transactions and contributed to the country reach its goal of reducing poverty. E-commerce capital has helped lower the costs of middlemen in the sale of agricultural goods through their online information platforms (F. Yang, 2021). In response, the central government has sent out documents to encourage the rapid growth of e-commerce in rural areas.

At this time, there are two main e-commerce models that have come up to lower transaction costs. The first is a model of collective agricultural e-commerce coordination in which e-commerce capital and village collectives work together. In this model, the collective acts as a negotiating manager. JD.com is a well-known example. It started working with other companies in 2014 and has since become one of the most popular platforms for cooperative agricultural product e-commerce. The second model is a decentralised agricultural e-commerce coordination model in which e-commerce capital works directly with individual farmers. This model has high overall transaction costs, but low costs per transaction and a high frequency of transactions. Soon after that, many of e-commerce platforms, like Pinduoduo, have come up to lower these costs even more.

Internet information technology has further addressed the challenges in agricultural product sales. By mitigating impeded information flow that leads to increased variable transaction costs and alleviating the issue of high fixed transaction costs resulting from the limited operational scale of farmers, internet information technology plays a crucial role in reducing these expenses (Hu et al., 2022a).

Furthermore, land trusteeship and land shareholding in China also contribute to reducing land rental costs and lowering transaction costs (Y. D. Wang et al., 2022). The evolution of agricultural production service models in county-level peanut specialized cooperatives in Hebei Province demonstrates the significant role of land trusteeship and land shareholding in reducing information acquisition costs and lowering procurement costs for production inputs in the agricultural sector.

2.1.3 Agricultural technolgy diffusion theory

From the perspective of communication theory, technological diffusion is defined as the spread of new technologies from initial adopters or regions to more adopters or regions through specific channels (Rogers, 2003). It plays a vital role in promoting economic and social development. Agricultural technology diffusion theory is a specialized branch of technological diffusion theory applied in the agricultural sector. It refers to a dynamic process, with its core being the collective manifestation of agricultural producers gradually adopting and practicing an innovative technology within a specific geographical scope. The driving force and source of this process are usually individuals or organizational entities that master the technology.

The representative perspectives of agricultural technology diffusion theory include the basic view and the adoption view. Starting from the 1920s, a series of scholars explored the characteristics, influencing factors, and diffusion speed of agricultural technology diffusion from multiple disciplines such as sociology, geography, and economics (L. Liu & Sun, 2025). Their research outcomes laid the theoretical foundation for agricultural technology diffusion theory and formed its basic view. Among them, Ryan and Gross (1943) studied the adoption rate and influencing factors of hybrid corn technology in Iowa, the United States. Their research marked the formal initiation of agricultural technology diffusion theory and provided a foundation for subsequent related theoretical studies.

Another representative perspective-the adoption view-focuses on farmers' technology adoption behavior. Scholars of this school recognize that the extent of agricultural technology diffusion cannot ignore the impact of farmers, the key subjects of technology adoption (R. Zhou et al., 2017).

As a specific application of technological diffusion theory in the agricultural sector, agricultural technology diffusion theory can also be systematically summarized into temporal diffusion theory, spatial diffusion theory, and spatio-temporal diffusion theory. In this process, the theory has achieved interdisciplinary development integrating sociology, geography, economics, and other disciplines. However, different from traditional technological diffusion theory, the unique characteristics of agricultural technologies and differences in diffusion objectives endow agricultural technology diffusion theory with distinct complexity and particularity (L. Liu & Sun, 2025). The particularity of the theory is reflected in the following two aspects:

First, agricultural technology diffusion is affected by natural conditions and regional environments. B. W. Li and Xu (2018) studied the adoption behavior of freshwater aquaculture

microbial technology among farmers at the administrative village level in China. They found that farmers' adoption and mastery of the technology showed spatial differences. Such spatial variations in agricultural technology diffusion are largely derived from differences in natural conditions. Especially in the field of TCMM cultivation, the diffusion of TCMM planting technologies is more strongly influenced by diverse ecological characteristics, as different TCMM materials require specific growing environments.

Second, agricultural technology diffusion is characterized by high risk. On one hand, crop growth requires a certain cycle and is highly dependent on natural conditions such as soil, light, and temperature. This means the effects of agricultural technology application can only become prominent after a relatively long period. In addition, the application of agricultural technologies often involves a long-term process from experimentation to continuous adjustment. On the other hand, there are various uncontrollable factors in the process of agricultural technology diffusion, such as plant diseases and insect pests, and market price fluctuations. W. W. Wang and Zhang (2022) conducted a survey on citrus-growing farmers in the Sichuan-Chongqing region of China and found that agricultural technology diffusion was slow. They pointed out that the adoption of citrus top-grafting technology by farmers takes 3-4 years to show results. Therefore, farmers with a higher degree of risk aversion have a lower adoption rate of this technology.

2.1.4 Farmers' behavior theory

Farmer behavior refers to a series of behavioral patterns exhibited by agricultural households during production and management processes. The theory of farmer behavior investigates how farmers make economic decisions in investment, production, operation, and consumption based on their own conditions and external environmental factors. Currently, academic research on this theory has primarily developed three mainstream perspectives.

First, farmers are rational economic agents whose goal is to make as much money as possible. Schultz supports this view of the "rational smallholder." He wrote a lot about the idea of the "rational smallholder" in his important book Transforming Traditional Agriculture (Schultz, 1964). He contended that although traditional agriculture is often marked by poverty, it demonstrates exceptional efficiency in resource distribution. Farmers, like businesses in a capitalist system, are rational economic agents who weigh costs and benefits in order to get the most benefit for themselves. Farmers will take steps to maximise their own profits once they realise that investing in production inputs and technology can help them do so.

Second, farmers' main goal is to meet the needs of their families, not to make as much income as possible. Chayanov (1996) argues that peasant households' function differently from capitalist enterprises, in contrast to Schult's "rational smallholder" perspective. He stresses that the main goal of these kinds of families is to be self-sufficient and meet their needs, not to make the most money as possible. The amount of funds invested in a family farm and the amount of hard work required are based on "a fundamental balance between how well family needs are met and how hard the work is."

Third, farmers make decisions about their behaviour based on two things: maximising their profits and maximising their utility. This viewpoint underscores the resilience and market growth potential of China's smallholder economy (Z. Z. Huang, 1986). He contended that family farms ought to be perceived as a cohesive entity of production and consumption. To understand why smallholders make the choices they do, it is necessary to combine theories of both business and consumer behaviour.

2.2 Definition of related concepts

2.2.1 "company + farmer" model

Contract farming refers to an arrangement in which farmers grow crops according to a company's requirements under a forward contract and sell the harvested agricultural products to the company as stipulated in the contract (S. Singh, 2002). The main participants in contract farming include companies and farmers, who operate independently. Contract farming provides companies with a more direct channel to participate in the cultivation and production process of agricultural products. Moreover, contract farming allows farmers to reduce the sales risk of their products and lowers the company's procurement costs, while aligning the interests of companies and farmers to achieve a mutually beneficial outcome (Ton et al., 2018).

Contract farming is a long-established agricultural system. Since the last century, developed countries such as those in Europe and North America have gradually begun to implement contract farming. For example, American multinational companies in Central America have adopted this agricultural system. By the late 20th and early 21st centuries, contract farming had been widely adopted in developed countries such as Western Europe, the United States, and Japan.

With market reforms in developing countries, contract farming gradually gained adoption in these regions. Influenced by the large-scale farm models of developed countries, developing

nations evolved a new "company + farmer" contract model adapted to their smallholder structures. As early as 1885, Japanese sugar refining enterprises began signing agricultural contracts with local farmers in Taiwan, China, to secure raw material supplies. Driven by higher incomes from export-oriented agricultural products and the introduction of new technologies, contract farming rapidly gained popularity across Asia, Latin America, and Africa (Kirsten & Sartorius, 2002).

More and more developing countries are focusing on contract farming. Contract farming has shown beneficial impacts on sales, production scale, and transaction costs in Ghana's broiler production sector in West Africa (Bannor & Gyekye, 2022). Ruml et al. (2022) utilized regression models to demonstrate that oil palm contract farming agreements in Ghana have augmented the incomes of local farmers. They also looked into where farmers get their revenue and found that simple marketing contracts and comprehensive resource-providing contracts are linked to how farmers make a living. In addition, contract farming can save farmers' labor. Farmers participating in contract farming can use surplus labor for non-agricultural activities and earn additional income.

However, the stability of contract farming is less assured in developing nations. In these contexts, where economies are heavily reliant on agriculture, contract defaults occur with notable frequency. To overcome this constraint, innovative contract models have started to develop. Abbasi et al. (2021) developed a resilient and varied social business contract farming model by amalgamating three fundamental business components: social capital, relational norms, and social business dimensions. This new type of contract farming helps to organize and stabilize the connection between contracts and the agricultural sector. This makes it a good choice for promoting contract farming practices around the world.

As a typical developing country, China has experienced the slow growth of contract farming. The distinctive Chinese model of agricultural contracting is the "company + farmer" arrangement. This model involves agricultural companies directly entering into contracts with farmers. The companies provide technology and production materials to the farmers, and upon harvest, purchase the agricultural products according to the contract terms. With the economic reforms and opening-up policies, this innovative operational model of contract farming began to be implemented in China. Simultaneously, the government has progressively strengthened the reform of the rural economic system, building on the household responsibility system and adopting a dual operational approach that integrates unified and decentralized management.

One of the earliest formal examples of the "company + farmer" agricultural operation model in China dates back to the 1980s. Guangdong Province's Wens Group began supporting

a local collective chicken farm in order to lease a township brick kiln, marking the inception of its first contracted farmer (D. Z. Li & Xie, 2017). After years of development, Wens Group has now grown into a large enterprise with a market capitalization exceeding 200 billion yuan, while simultaneously helping nearly 60,000 contracted farmers achieve shared prosperity.

Agricultural industrialization further propelled the development of the "company + farmer" model. By the early 21st century, after over two decades of reform and opening-up, the disparity between rural and urban areas in China had begun to widen. To address the inherent conflict between small-scale farming and large-scale market demands characteristic of China's context, and simultaneously to tackle the "three rural issues" (agriculture, rural areas, and farmers), agricultural industrialization became an urgent priority. The integration of production, processing, and sales into a single operational chain is what constitutes agricultural industrialisation. This model operates based on the tenets of a market economy and is inherently attuned to market demand (Jia, 2006).

The primary three parties in the organisational structure of agricultural industrialisation are farmers, intermediaries, and the market. Intermediate organisations, such as leading businesses, supply and marketing cooperatives, and wholesale markets, are the most important link between farmers and the larger market. The "company + farmer" model has become the most common way to manage farms in China among these structures. This model links top companies directly to farmers through contracts. The "company + cooperative" model has also become more popular recently. In this setup, companies purchase farm goods from farmers by making deals with their supply and marketing cooperatives.

2.2.2 Companies

In the "company + farmer" contract farming model, the company is generally specialized in the production, processing, or sales of agricultural products, has a certain scale, meets the national business operation standards, and is recognized as an agricultural-related company by government authorities (J. M. Li, 2013). They sign contracts directly with farmers or carry out coordination, enabling farmers to access the market, improve their cultivation techniques, and ensure the quality of raw materials for production and processing, thereby enhancing sales operations. In contract farming, companies not only sign agricultural contracts with farmers and outsource the production of agricultural products to them but also act as processors of agricultural products. Some people call these agri-processing companies "principals," and they give farmers the job of making certain agricultural products according to the terms of the

contracts. Most of the time, the farmers or agents are smallholder farmers (Bellemare & Lim, 2018).

Given the significant regional disparities across China, the government categorizes agriculture-related companies into national, provincial, municipal, and county-level leading agricultural commercialization companies based on local economic conditions, transaction scales, company size, profitability, and their capacity to drive farmer engagement, among other indicators. To further standardize the recognition and supervision of national key leading companies in agricultural industrialization, China also promulgated the Measures for the Recognition and Operation Monitoring Management of National Key Leading Enterprises in Agricultural Industrialization in 2010.

2.2.3 Farmers

A farming household is a socio-economic unit organized by family, engaged in agricultural production and management, fulfilling both social and economic functions. The resource allocation behavior of this primary organization, when conducting family operations, is governed by survival rationality rather than complete economic rationality. Following China's reform and opening-up, the implementation of the Household Responsibility System gradually established the dominance of household economies in rural areas (Q. H. Shi, 2000). In this study, the term "farming households" refers to rational agricultural producers who pursue profit maximization.

Why do farmers need to participate in contract farming? According to surveys, small farmers in developing countries are often very poor. Through procurement agreements between companies and farmers, contract farming can effectively enhance the ability of small farmers to participate in the market (Meemken & Bellemare, 2020). Contract farming also increases employment, boosting local job opportunities, allowing small farmers to expand their cultivation scale, increase household income, change the underdeveloped rural situation, and promote the scaled development of agriculture in developing countries.

The willingness of small farmers in developing countries to participate in contract farming is influenced by many factors. Vamuloh et al. (2020) have identified several important reasons that hinder small farmers from participating in oil palm contract farming. First, when contract farming agreements contain terms unfavorable to smallholder farmers, they are reluctant to participate. Second, when contract farming agreements lack fairness—meaning smallholders lack bargaining power and feel exploited—they also choose not to participate. However, when

smallholders can access agricultural technology and production investments through contract farming, and gain entry to the open agricultural market for trading, they become more willing to participate.

Additionally, A. Pandit et al. (2015) found that smallholder and marginal farmers represent a category of farmers with relatively weaker risk resilience. They require contract farming to access advanced agricultural technologies, secure greater profits, and mitigate market risks. Simultaneously, the lack of safeguards for smallholder and marginal farmers within traditional agricultural markets further motivates their participation in contract farming.

2.2.4 Coordination mechanisms

As defined by Malone and Crowston (1994), coordination is the management of dependencies among activities. The examination of the mechanisms underlying this process constitutes an interdisciplinary endeavour that scrutinises the management of shared resources, producer relationships, simultaneity constraints, and task dependencies. This field brings together ideas from many different fields, such as psychology, computer science, operations research, and organisational theory. Conflicts arise from managing dependencies among coordinating organizations. Stronger dependencies necessitate more coordination. Each entity possesses independent decision-making authority, information, and objectives. In the process of pursuing benefit maximization, information asymmetry can lead to opportunistic behavior and bounded rationality, thereby making system coordination more complex.

Coordination serves as the core driver of supply chain management, representing the shared responsibility among members for planning, execution, management, and performance measurement information (Min et al., 2005). As a result, working together in the supply chain gives all parties more benefits. But if every part of the system puts making the most money ahead of the interests of other members, the system may break down. This could stop the system from working as well as it could if everyone worked together. Supply chain coordination also means that all the businesses in the supply chain agree to act in ways that improve the system's overall performance, which makes the whole supply chain more competitive.

Contracts are significant for keeping supply chains growing in a sustainable way. Contracts, also known as agreements, are usually formal arrangements that spell out the rights and responsibilities of both supply and demand parties in the supply chain system. To get the system to collaborate effectively, the contract design must follow certain rules and change the right parameters to get the most benefit for both sides. It might also mean updating information and

improving technical skills so that both sides can get the most out of the deal (B. Liu, 2005).

The “company + farmer” model works within supply chains, and its healthy growth depends on how well coordination mechanisms perform. Abdul-Rahaman and Abdulai (2020) examined the factors that influence vertical coordination mechanisms and discovered that contract farming enables smallholders to engage in larger agricultural markets, although various contract types impact their income levels. Smallholders who do spot market transactions make less money than those who do contract farming through written or oral agreements. Contract farming can also improve the performance of farms, the productivity of workers, and the difference between prices.

From the viewpoint of contract theory, contract farming fundamentally functions as a means of risk transfer. Bellemare et al. (2021) discovered that contracts serve as an insurance mechanism in contract farming in Madagascar when there are potential market risks. Specifically, they pointed out that fixed-price contracts are essentially the only insurance mechanism for maintaining stable incomes for farmers in contract farming.

As organic agricultural products gain increasing attention, scholars have begun analyzing their production characteristics to enhance the competitiveness of organic agriculture and promote its sustainable development. Research has also focused on the coordination mechanisms between organic farmers and organic agricultural companies (Nematollahi et al., 2021).

2.2.5 TOE theoretical framework

The TOE framework, originally proposed by Tornatzky and Fleischer (1990), aims to explore the factors affecting the adoption and diffusion of new technologies at three levels: technology, organization and environment. The technology dimension focuses on the characteristics associated with the technology itself, including both internal technologies within the organization and externally available technologies. The organization dimension focuses on the characteristics and resources within the firm. The environment, on the other hand, refers to the external macro and micro environments in which the organization operates. This framework has been widely adopted by scholars to study organizational technology adoption (Abed, 2020). Over time, the application areas of the TOE framework have expanded (Z. Zhang et al., 2024). For example, the framework has been applied to enterprise quality development (Z. Zhang et al., 2024), digital and intelligent transformation (Zhong et al., 2025), and natural resources utilization efficiency (S. Zhang & Cao, 2025). Overall, the TOE theoretical framework is

utilized with a high degree of flexibility and applicability (Al-Khatib, 2023).

The improvement of TCMM is affected by a variety of factors from multiple actors, including farmers' adoption of cultivation technology, the company's willingness to share technology, and the organizational synergy between the company and farmers, as well as external government support. Therefore, this study uses the TOE framework to investigate the effects of agricultural technology diffusion at the technological level, supply chain synergy at the organizational level, and government support within the environmental context on the quality of TCMM in the "company + farmer" contract farming model.

2.3 Literature review on contract farming

2.3.1 Advantages and disadvantages of contract farming

Contract farming is a comprehensive institutional arrangement that combines the strengths of companies and farmers. Farmers could benefit from contract farming to the extent that materials and financial resources were supplied by companies before production. In this case, farmers could establish connections with more profitable markets (Ton et al., 2018). If implemented well, the contract farming was able to reduce costs in companies, keep the supply-demand relationship stable in the agricultural supply chain, and protect the interests of peasant households (A. B. Pandit et al., 2009).

The benefits brought by contract farming were confirmed from early studies on the development of national contract farming strategies. As prior studies noted, the application of contract farming in the U.S. food industry lowered transaction costs, if analyzed in terms of vertical coordination (Frank & Henderson, 1992). Contract farming systems at scale demand vertically integrated synchronization along production networks, coupled with transparent information flows. Vertical information sharing and coordination between farmers and agribusinesses in the pork sector were enhanced through contract farming, resulting in superior quality of agricultural products (Hennessy & Lawrence, 1999). In 2004, the University of New England conducted an agricultural research in developing countries. The report revealed structural advantages of vertically integrated contract farming: Such alliances between companies and peasant households systematically reduced dual risks of commodity volatility and quality variance, enabled land consolidation for scaled cultivation, while garnering institutional reinforcement from local governments (Australian Centre for International Agricultural Research, 2004).

Related studies have further explored the potential benefits of contract farming from the perspective of supply chain coordination. A study on the U.S. supply chain of agricultural products, for example, found that contract farming shortened the distance of agricultural products to consumers (Barkema, 1993). Given the ever-changing preferences of consumers for food, food processors raised quality requirements for agricultural products produced by farmers in response to consumer demands. This ultimately enhanced their responsiveness to consumer demands. According to a case study on the pricing of beef in North America, contract farming could enable members at all stages of the beef supply chain to achieve joint vertical coordination. This way could avoid flaws in pricing strategies. Livestock farmers and processors might share information about the cattle breeding process, so that the processed beef met the demand of consumers (Tronstad et al., 2005).

Developing countries have also adopted contract farming in the process of agricultural industrialization. Agricultural contracts have promoted agricultural innovation in developing countries (Otsuka et al., 2016). For example, in African contract farming, the approach of vertical project coordination can reduce risks such as the sale of agricultural products and ensure small farmers' income (Kirsten & Sartorius, 2002). Evidence from potato farmers in Pakistan indicates that participation in contract farming is positively correlated with higher income (Khan et al., 2019). Under the condition that the influencing factors of the system could be controlled, Ugandan farmers were able to achieve positive income effects, according to a study on contract farming for organic coffee in the tropical region of Uganda in Africa (Bolwig et al., 2009).

Besides, contract farming can bring additional benefits to families. A study on contract farming in Madagascar showed that peasant households could enhance their ability to combat hunger by participating in contract farming. Such food safety benefits were more pronounced in families with a greater number of children, especially girls (Bellemare & Novak, 2017). The survey in six developing countries revealed that families involved in contract farming could earn higher incomes and even increase their demand for employed labor force (Meemken & Bellemare, 2020). This indicates that contract farming can generate positive externalities and stimulate employment.

Contract farming can also help farmers achieve poverty alleviation. Oil palm farmers in Indonesia who participate in contract farming are able to alleviate their own poverty to some extent (Cahyadi & Waibel, 2016). Furthmore, evidence from rice cultivation in Ghana indicates that participating in contract farming can improve food security by 109% through enhancing the quality of rice and farmers' incomes (Binpori et al., 2021).

However, contract farming has also shown various problems since its development. Some scholars have questioned whether contract farming truly improves welfare (Bellemare & Bloem, 2018). This is because, in contract farming, the goal of profit maximization for companies currently does not align with the goal of maximizing farmers' income. Previous empirical studies have recorded evidence that farmers participating in contract farming often drop out (Andersson et al., 2015).

When farmers enter into contract farming agreements, they often find themselves at a disadvantage compared to businesses. In contract farming, small-scale farmers working at the household level have a hard time getting good benefits in a free market. If the products grown by farmers do not meet standards, the products grown by farmers may have their purchases reduced or be refused (Martin & Mwaseba, 2015). Companies can use contract farming to create a monopoly on purchases, which can make farmers distrustful and take advantage of them. For instance, farmers in Rajasthan who are growing barley on contract must keep the harvested grains for a while until the company that hired them purchases them (R. Singh et al., 2013). This delayed purchase is definitely unfair to farmers.

Contract farming can introduce considerable environmental risks for participating farmers. Monoculture is a major concern, and it is a risk that has been found in company-led contract farming in Laos. Bounmasith and Li (2018) assert that when contracts inadequately delineate regulations concerning debt or the application of pesticides and insecticides, the risk of yield loss for farmers significantly escalates. In addition to these operational risks, other things threaten the fulfilment of contracts, such as agreements that are not complete and the fact that natural disasters are always a possibility (L. Zhang, 2021).

In addition, besides the pressure from the dominant party in contract farming—the companies—farmers also face competition with other farmers. In order to secure opportunities in contract farming, small farmers are prone to resorting to malicious competition with each other to gain benefits (Mi, 2003).

Contract farming may also generate negative externalities, having adverse effects on the ecological environment and sustainable development. Although contract farming can reduce risks related to the sale of agricultural products and ensure the income security of small farmers, it can also cause them to lose some degree of autonomy and create production risks. For example, contractors may intensify land use to increase profits, which can lead to environmental pollution and ultimately result in a decline in both the yield and quality of agricultural products (Kirsten & Sartorius, 2002).

A survey of cashew agriculture in Ghana, a developing country, also confirmed this. Farmers willing to participate in contract farming tend to focus more on yield and profit, rather than adopting environmentally friendly production methods, which may lead to damage to the environment and soil ecology (Dubbert et al., 2023). These farmers participating in contract farming can reduce the sustainability of agriculture. Olounlade et al. (2020), in their study of rice cultivation in Alibori Province, Benin, found negative impacts of contract farming. When agricultural production resources and the agricultural economic environment are not adequately prepared, it affects the sustainable development of local rice farming. In such cases, the more farmers that participate in contract farming, the more likely it is that both grain quality and agricultural product income will decline.

In summary, previous research has revealed the direct benefits that participation in contract farming brings to farmers, including increased crop yields, income, and profits. In addition, contract farming also has spillover effects, playing a positive role in ensuring food security, food safety, and increasing employment. However, the disparity in bargaining power among participants in contract farming to some extent hinders its healthy development and gives rise to a series of problems. As a typical industry employing contract farming, TCMM planting sector also faces common issues associated with contract farming. Reviewing the advantages and disadvantages of contract farming can provide references and suggestions for exploring high-quality TCMM planting models in China.

2.3.2 Factors influencing farmers participation in contract farming

The balance of power among participants in contract farming helps establish stable cooperative relationships and achieve the sustainable development of contract farming (Q. Wang et al., 2013). However, farmers often find themselves at a disadvantage in terms of information and power in contract farming, with relatively weak bargaining ability. Companies usually have more control over the quality, quantity, and specifications of products in contract farming agreements (Kim & Gómez, 2024). They get a bigger piece of the value-added gains in contract farming and are often open to making deals with farmers. But farmers are very sensitive to how fair contract farming deals are because they are in a bad position. There are many things that can make farmers leave contract farming. Thus, the things that affect farmers' decision-making to join or leave contract farming are very important and need to be looked at right away.

Previous studies have established that farmers' readiness to engage in contract farming is affected by various factors, including individual farmer traits, farm attributes, company

characteristics, and governmental support, all of which influence farmers' decision-making to participate in contract farming. First of all, the terms of the contract are closely related to how willing farmers are to participate in contract farming. Abebe et al. (2013) did a survey to see if Ethiopian potato farmers would be willing to work on contract farms. They pointed out that farmers demonstrate a strong preference for contracts that are formalized in writing. In terms of specific contract terms, contracts that clearly provide farmers with inputs, technical assistance, and high-quality potato seeds, as well as contracts with variable output quantities and prices, are more welcomed by potato farmers.

Similarly, the studies shows that, the strict product conformity requirements from the market depressed adoption rates of contract farming among farmers in Nepal's emerging modern supply chain of vegetables (Kc et al., 2022). By comparing the contract farming in Ghana, India, Madagascar, Mozambique, and Nicaragua, existing literature found that marketing prices, payment methods, and delivery terms were the key determinants for the participation of farmers in contract farming (Barrett et al., 2012). In addition, here's a case study on oil palm cultivation in Ghana. The results showed that unfavorable contractual terms and the perception of unfairness in contract farming accounted for why farmers refused to participate in order farming (Vamuloh et al., 2020). However, this study revealed that access to critical agricultural inputs and entry into mainstream markets were key motivations for small-scale farmers to participate in contract farming. In addition, the delayed payment of the contract amounts to farmers was another hindrance in the participation in contract farming (Pham et al., 2021). On the contrary, high prices and timely payment might attract farmers to participate in contract farming.

Secondly, the inclination of farmers to contract farming was subject to their demographic characteristics and farm sizes (Jaime & Salazar, 2011). The farmers with larger cultivation areas, higher ownership and educational levels were more likely to choose contract farming that was able to play a greater role in input supply and crop control (Golestanian et al., 2020). A case study of rice production in the Mekong Delta of Vietnam found that farm size, cooperatives, expansion, market access and trust have positive effects on farmers' participation in contract farming (Pham et al., 2021).

The farmers with extensive agricultural experience and accessible to credit or financial support were more likely to participate in contract farming, however the higher educational levels made them less likely to engage in contract farming (Loquias et al., 2022). Based on a study on the influencing factors of contract farming in the U.S. pig industry, the farmers with lower educational levels and less advanced breeding techniques were more willing to participate

in contract farming. The farmers' lack of funds and concerns about risks are also the main reasons that affect their participation in pig breeding order agriculture (Key & McBride, 2003). However, some studies pointed out that farmers with rich agricultural experience were reluctant to participate in contract farming, since they had already developed a set of their own farming practices over a long period of agricultural activities (Shankar et al., 2010).

The risk-takers and farmers with larger farms were more willing to participate in contract farming, while female housewives and households with abundant labor force were less inclined to adopt contract farming, based on a survey of farmers growing vegetables in Shandong Province, China (H. H. Wang et al., 2011). This result implies that Chinese farmers mainly participate in contract farming to seek better prices and lower transaction costs. However, a survey conducted among farmers in Vietnam indicated that the female household heads are more likely to participate in contract farming, while those with higher educational levels may hinder family participation in contract farming (Hoang & Nguyen, 2023).

Similarly, a study on the factors influencing broiler farmers' participation in contract farming in Indonesia revealed the impact of farmer heterogeneity on their decision-making to engage in contract farming. This case in the poultry sector documented a positive correlation between education level, land size, household population, farmer groups, and agricultural extension with farmers' participation in contract farming (Rondhi et al., 2020). In addition, Khalili et al. (2024) investigated the factors affecting farmers' willingness to participate in contract farming in rural areas of central Iran from three perspectives: personality, social, and cognitive. They found that personality, interpersonal relationships, and knowledge and skills influence people's behavioral choices. Trust, awareness, and attitudes significantly affect farmers' willingness to participate in contract farming.

Third, the type of crops grown also affects whether farmers decide to participate in agricultural contracts. Existing research has found that in Vietnam, the rice sector receives more support and encouragement in contract farming compared to the coconut sector. Therefore, farmers who grow rice are more willing to participate in contract farming than coconut farmers (Hoang & Nguyen, 2023).

Fourth, in developing nations, governmental policy interventions can also affect farmers' readiness to engage in contract farming. Government support in the form of input support, price support, technical assistance, and financial backing has been shown to have positive effects on agricultural output (Lencucha et al., 2020). A randomized study in Kenya showed that agricultural insurance encourages farmers to take part in contract farming (Casaburi & Willis, 2018). A 2002 empirical study of contract farming in Senegal demonstrated that social collateral

loans facilitated the participation of economically disadvantaged farmers in contract farming. Contract farming allows small farmers in poor areas of developing countries to get technical help and production resources. This encourages them to get involved in contracted agricultural production, which helps them get out of poverty and get stable incomes (Warning & Key, 2002).

Most studies on contract farming have focused on looking at what factors make farmers want to take part in these kinds of deals. These factors are quite broad and include things like the farmer's own traits, how the farm is run, the business's traits, the types of crops grown, the terms of the contract, and the amount of government support. Nevertheless, owing to substantial disparities in economic, cultural, and political development among countries and regions, numerous scholars have arrived at conflicting conclusions regarding analogous research subjects. For example, current research has not yet reached an agreement on how farmers' willingness to participate in contract farming is affected by their education level and experience in farming. China is a traditional agricultural powerhouse, but its agricultural development is different from that of other countries. The "company + farmer" cultivation model for enhancing the quality of TCMM relies on the involvement of farmers in this contract farming methodology. Looking at what made farmers want to do contract farming in the past will help this study find possible ways to improve quality when looking into the "company + farmer" cultivation model for TCMM in China.

2.3.3 Governance approaches to promote contract farming development

Contract farming is very important for helping smallholder farmers get around challenges with market access. Prior studies have underscored its beneficial impact on augmenting farmers' income, improving crop yields, guaranteeing food security, aiding poverty reduction, and fostering employment (Otsuka et al., 2016). Nevertheless, farmers often stop participating in contract farming after they start (Andersson et al., 2015). A survey of fruit farmers in China found that 38% of farmers had broken the contract (Hou et al., 2019). There are mainly two reasons for this phenomenon:

First, the breakdown of contract farming systems is caused by information asymmetry in agricultural contracts. In practice, companies often do not give farmers full and equal access to information resources because there are big differences in the amount of information that companies and smallholder farmers have. This information imbalance makes smallholders think that companies are opportunistic based on limited and possibly wrong information. As a result, the basis of trust in businesses is severely weakened, and levels of trust drop significantly.

In this situation, the subjective willingness of many small farmers to participate in contract farming is clearly insufficient, and their enthusiasm is frustrated. Moreover, the trust crisis caused by information asymmetry further leads to frequent breaches of contract during the execution of contract farming agreements. The breach rate is on the rise, negatively affecting the stable development and sustainable advancement of contract farming (Ruml & Qaim, 2021).

Second, farmers are forced to exit contract farming if their products fail to meet the quality requirements of the contract or violate the contract terms. A survey of the broccoli market in Ecuador found that companies' rejection of products and long payment delays increased farmers' transaction risks, forcing them to exit the high-value broccoli export chain. When facing transaction risks, poorer households and female-headed households tend to exit contract farming more quickly (Romero Granja & Wollni, 2018). Surveys of contract farming programs in India also found that farmers were forced to exit contract farming due to their inability to supply high-quality products (Silva et al., 2013).

Therefore, how to maintain the stable development of contract farming and establish a healthy interactive relationship between companies and farmers has become a concern for many scholars. For enterprises, when the contract price exceeds the spot market price, there is an incentive to withdraw from contract farming in order to obtain more profit. However, large upfront investments and significant reputational losses can restrain companies from breaching contracts (H. Guo et al., 2007). Consequently, current governance aimed at promoting the development of contract farming mainly focuses on farmers as the primary actors.

Alleviating information asymmetry is an important means to promote the development of contract farming. In particular, in contract farming in developing countries, information asymmetry between companies and farmers is quite common. A survey of small dairy farmers in Vietnam found that farmers who were granted the authority to independently verify milk testing results in contract farming would proactively increase related investments and had a positive impact on improving farm productivity (Saenger et al., 2014).

The coordination between farmers and company authority also plays an important role in helping to establish healthy contract farming relationships. In situations with incomplete contracts, opportunistic problems inevitably arise in agricultural industrial operations. Farmers with independent management rights are more willing to fulfill contract farming agreements (Q. Wang et al., 2013). A study on contract design in Danish agriculture revealed that resolving coordination issues between both parties in contract farming is the most important aspect (Bogetoft & Olesen, 2002). Contract design should also pay attention to the delegation of decision-making authority. If decision-making power lies with the farmers, the contract design

should incentivize producers to avoid moral hazard issues; distributed decision-making helps prevent opportunistic behavior. An effective contract needs to balance risk-sharing and incentive measures. Including renegotiation clauses in contracts can make them more flexible when environmental conditions change, but it may affect the effectiveness of incentives.

Market risks have increased the instability of contract farming. It is necessary to establish standardized product and contract norms to make contracts more stable, balance the power between companies and farmers, and restrain companies from excessively transferring risks to farmers (L. Zhou & Long, 2019). In China, the conflict between traditional small-scale farmers and the modern large market hinders the healthy development of agriculture. Scholars have conducted related research exploring how to enhance farmers' voice in contract farming. In China, farmer-dominated models in contract farming include "cooperative + farmer" and "professional association + farmer," which can address the problem of buyer opportunism. Company-dominated models are "company + farmer," where farmers control production-stage specific resources and decision-making. The company dominates processing-stage specific investments and decision-making, allowing farmers to protect their interests. Processor-dominated models are led by companies running the agricultural business, which can address the issue of farmer opportunism (Z. H. Huang & Wang, 2002).

Additionally, China has a lot of smallholder farmers who are spread out and can not handle market changes or high transaction costs very well. Contract farming's set variety, quantity, and price of agricultural goods can greatly reduce the risks and uncertainties that farmers face (F. Q. Liu, 2003).

For farmers' interests to be protected and contract farming to grow, there must be long-term and effective ways to supervise and enforce the rules. Regulatory standards set by the industry can help competition be fair and the industry be stable (Mukucha & Chari, 2021). A survey of Polish pig farmers indicated that the majority did not view the court system as an effective mechanism for contract enforcement with enterprises. Nevertheless, empirical analysis revealed that the law can significantly influence the conduct of participants in contract farming (Beckmann & Boger, 2004).

Some research has also looked into ways to keep contract farming stable from the point of view of coordinating the supply chain. In a supply chain system, the centralized decision-making model helps reach the best possible output level. In contrast, the decentralized decision-making model can find one best solution that maximizes farmer' profits. However, from a holistic benefit point of perspective, the centralized decision-making supply chain system is much more efficient overall. Prior researchers have creatively developed a contractual

framework predicated on a revenue-sharing coefficient and profit margin. This mechanism uses these two important factors to make sure that the benefits are distributed fairly and efficiently between the supply chain's upstream and downstream participants (X. Liu et al., 2020).

In addition, some studies have explored the impact of this policy on the performance of contract farming from the perspective of China's "minimum purchase, market-following" agricultural support policy. This policy can effectively buffer the risk shocks caused by fluctuations in wholesale prices in the secondary market, creating a relatively stable production expectation environment for farmers and encouraging them to allocate production factors reasonably in their activities, thereby maximizing production efficiency. From the enterprise perspective, minimum-price purchases help reduce various transaction costs such as information search costs and negotiation costs in the transaction process, strengthen strategic coordination among supply chain members, and enhance the overall resilience and stability of the supply chain. As a result, the supply chain can maintain a more balanced and sustainable development pattern in terms of quantity planning, profit distribution, and profit acquisition (Qin & Li, 2016).

With the development of technology, the role of big data in maintaining the alliance relationship between farmers and companies in contract farming has also become prominent. Digital technology can not only play a positive role in helping companies understand farmers' learning of planting techniques, but also identify and control potential risks in contract farming (Wolfert et al., 2017). A survey of 303 agricultural integrated enterprises in China found that big data analytics can improve risk management capabilities in contract farming.

On one hand, big data analytics technology can effectively help farmers and companies identify weather disasters, diseases, and pests, which helps reduce production risks. On the other hand, big data analytics technology plays an important role in estimating agricultural product yields, as well as in food safety and quality testing, predicting market supply and demand, and reducing and responding to market uncertainties (S. Lin et al., 2022). A dual strategic orientation of digital guidance and corporate social responsibility activities can improve the quality of the relationship between companies and farmers, fostering trust, satisfaction, and commitment between them, enhancing coordination quality, and ultimately promoting the stability of cooperative relationships (J. Lin et al., 2024).

In summary, the current body of literature has thoroughly examined effective strategies to foster the healthy evolution of contract farming and to cultivate stable cooperative relationships from various perspectives, including contract design and power coordination, governance frameworks and enforcement strategies, supply chain coordination and optimization, along with

the facilitation of digital technology. These studies together make a complete framework for dealing with the common problems that come up in contract farming. This framework is particularly relevant to the TCMM sector. Because it is specialised, has complicated quality characteristics, and there is a big information gap between participants, the insights from these studies are especially useful in this case.

2.4 The diffusion of technology in contract farming

The theory of agricultural technology diffusion refers to the process of spreading agricultural technological innovations over time and space. It generally includes the promotion of agricultural technologies, farmers' learning and use of new agricultural techniques, and improvements. The diffusion of agricultural technology has brought many positive impacts. For example, Ukraine has introduced information system management and enterprise management into agricultural management when implementing precision agriculture, enabling accurate agricultural cultivation and enterprise management. By promoting advanced information technology achievements in agricultural industrial complexes and completing the collection, analysis, and management of agricultural data, not only can agricultural production efficiency and product quality be improved, but agricultural enterprises can also develop in an energy-saving and environmentally friendly manner (Kopishynska et al., 2020).

One of the important advantages of contract farming is its ability to facilitate the transfer of knowledge and technology from agricultural companies to farmers within a relatively stable contractual relationship. Currently, many scholars are exploring the benefits of contract farming in promoting technology diffusion.

At the same time, given the significant benefits that the diffusion of agricultural technology brings to agricultural companies, farmers, and the agricultural industry, exploring the factors that influence the diffusion of agricultural technology and clarifying the mechanisms that promote it is also a topic of great interest to scholars.

2.4.1 Economic consequences of agricultural technology diffusion

The contract-based farming can promote farmers' adoption of technology and bring benefits of improved yield and quality. As the main participants of cooperatives in order farming, family farms in China can better learn advanced agricultural production technologies and increase the output of agricultural products (Gong et al., 2019). Based on a survey on farmers growing apples and scallions in Shandong Province, China, the participating in contract farming

exhibited significantly higher uptake rates of precision farming technologies and premium-grade agricultural inputs. The high-quality seeds and pesticides provided by the agribusiness entities, as well as the spraying services, effectively minimized pesticide traces and optimized the market-grade attributes of apples and scallions produced by farmers (Miyata et al., 2009).

The technology diffusion through contract farming mechanisms significantly contributes to the income growth of farmers. A survey of rice farmers in Sichuan Province of China found that contract farming can help farmers overcome obstacles to investment in agricultural production by bringing economic benefits to farmers. The farmers participating in contract farming will increase the use of environmentally sustainable control technologies, manual weeding and organic fertilizers, ultimately achieving the dual goals of farmer welfare and sustainable agricultural development (Ren et al., 2021).

Another survey on vegetable producers in Lushoto, Tanzania, made similar findings: Compared to registered farmers' organizations, contract farming had a significant advantage in helping small-scale peasant households respond more quickly to changes in market conditions. Specifically, the contract farming for vegetable production in Lushoto, Tanzania, featured a formal quality control system, which allowed the introduction of new technologies (new varieties, new fertilizers or pesticides), and the monitoring of their adoption by peasant households (Gramzow et al., 2018).

Allowing for the growing recognition of the importance of sustainable development, increasing studies are found to explore the role of contract farming in achieving sustainable agricultural development. Contract farming stands as an important medium for the dissemination of material capital and knowledge capital. Y. R. Yang (2025) pointed out that rice farmers participating in contract farming could obtain green farming techniques from companies to alleviate the risk of their own technical shortage. Meanwhile, as a channel for information transmission, contract farming reduced the risk of information asymmetry faced by rice farmers, and enhanced their confidence in growing rice. As a result of contract farming, the effect of technology diffusion improves the farming skills and incomes of peasant households, and even promotes the sustainable development of the agricultural sector. As the supply chain develops, peasant households have shown more urgent pursuit to common interests. Common interests could balance the power relations in contract farming and facilitate sustainable agricultural development (Kim & Gómez, 2024).

Some literature has more directly explored the positive effects of contract farming in improving technical levels of peasant households and achieving scale effects. Under the contract farming model, companies can provide peasant households with professional technical

guidance, thereby improving their technical and management skills. Jiang et al. (2025) pointed out in their research of pig breeding industry that contract farming enabled peasant households to obtain the intelligent breeding equipment provided by companies. The equipment allowed for precise feeding and clean production of pigs, contributing ultimately to increased production efficiency and reduced emissions. The survey data from 410 vegetable farmers in Hebei Province and Zhejiang Province of China also confirmed that contract farming offered work safety training and technical services to peasant households. This encouraged them to produce vegetables in accordance with the standardization and food safety requirements, ultimately promoting the improvement of work safety behaviors in peasant households (L. Li & Guo, 2019).

The technology diffusion effect that comes from contract farming can also help farmers get out of poverty. China has long been known for its smallholder farming, which is a common way to farm in the country. China has come up with a plan to revitalize rural areas to speed up growth that is being held back by the large number of smallholders. A. Y. Guo and Li (2025) discovered that Jiangsu Province successfully integrated agricultural technology with scientific and technological advancements through the innovation and dissemination of agricultural techniques. Specifically, urban-level agricultural technological innovation can help increase the level of mechanization in agriculture and the efficiency of land output. This will lead to the revitalization of rural areas and the growth of China's agriculture.

Based on the research above, it is clear that contract farming is very important for spreading and modernizing agricultural technology in many ways. Contract farming directly improves the quality and quantity of agricultural products by allowing farmers to get corporate technical help and high-quality production inputs through contracts. The spread of agricultural technologies also helps farmers make more money and get out of poverty. The widespread adoption of agricultural technologies, especially green and smart ones, will help the whole agricultural industry grow in a way that is good for the environment in the long run. Contract farming is an important part of improving agricultural technology, protecting farmers' rights, and helping with national development plans.

2.4.2 Factors influencing the diffusion of agricultural technologies

The diffusion of agricultural technology has unique features because its scope and pattern are shaped by the historical and social contexts of the area. This section brings together different points of view on what affects the spread of agricultural technology. Its goal is to provide a

theoretical basis for the next step, which is to look at how technology dissemination in the "company + farmer" model in the TCMM planting sector leads to better quality.

Farmers are the main people who use technology, and their different levels of knowledge, social resources, and farm size all affect how technology spreads. Some researchers have performed simulation analyses regarding agricultural technology knowledge behavior within the "company + farmer" framework. Utilizing MATLAB for programming and computational analysis of critical factors influencing agricultural technology diffusion, their research concluded that the improvement of farmers' knowledge behavior positively impacts the extent of agricultural technology dissemination. Well-established rural social networks, along with a moderate risk appetite and altruistic psychological inclinations among farmers, enhance the efficacy of agricultural technology dissemination (R. Zhou et al., 2017).

Another survey-based study of Chinese maize farmers found that differences in the size of the land they farm, their income, and where they live make farmers at different scales much less likely to adopt new technologies. The study points out that by analyzing how farmers' technology selection preferences and behavioral differences affect crop yields and agricultural technology utilization efficiency, the effectiveness of key technologies in grain production can be better evaluated, thereby facilitating more targeted agricultural technology diffusion (Jin, 2019).

Furthermore, an empirical study analyzing agricultural technology knowledge adoption behavior in China using a Probit model found that larger farms exhibit greater willingness among farmers to adopt new agricultural technologies. These farmers invest more time and capital in learning and enhancing agricultural production techniques, whereas smaller farms demonstrate lower willingness to acquire such knowledge (Hu et al., 2022b). A study on the drivers and barriers of renewable energy system adoption on Spanish farms pointed out that contract farming, interest in new technologies, and risk tolerance can promote farmers' use of renewable energy systems (Pombo-Romero et al., 2023).

Social networks facilitate communication and interaction among different individuals, promoting the diffusion of agricultural technology. Social networks enhance trust, information sharing, and knowledge exchange among their members. Some scholars have studied the different ways agricultural technology knowledge flowed among small farmers in China during different periods and pointed out the important role that agricultural knowledge networks and rural social networks play in technology diffusion (H. Yao et al., 2021).

Similarly, in order to address the severe environmental pollution problem, some scholars have explored the role of social networks in the diffusion of environmentally friendly

agricultural technologies. With the acceleration of agricultural development in China, pollution from agriculture has become increasingly serious, and pesticides and fertilizers have been used long-term, and even excessively, by smallholder farmers. Given China's national conditions, pollution control methods for agriculture from developed countries cannot achieve good results in China. They studied effective ways to promote the diffusion of environmentally friendly agricultural technologies in China. Among them, social networks (kinship networks, business networks, and functional networks) can help solve the difficulties of promoting environmentally friendly agricultural technologies in rural areas (Cai et al., 2022).

Surveys from other countries internationally have also confirmed the important role of networks in the diffusion of agricultural technology. A survey report on agriculture in northern Belgium showed that networks help enhance agricultural technological innovation. The author conducted in-depth interviews with local farmers and network coordinators in Flanders and found that the process of innovation can only occur under knowledge-intensive conditions. The main agents of technological innovation need to engage in extensive information exchange with other individuals and the outside world, as well as continuously engage in self-learning. Knowledge providers within the network structure also need to integrate with each other, and network coordinators help establish connections among multiple stakeholders. All these network factors collectively influence agricultural technological innovation (Lambrecht et al., 2018).

Some scholars have studied the characteristics of big data-driven agricultural technology dissemination. They integrated the technology acceptance theory, evolutionary economics theory, and transaction cost theory to propose mechanisms at various levels for the diffusion of agricultural technology. Specifically, they found that digital technology optimizes the information environment. It can provide comprehensive basic data and precise decision-making support for traditional agricultural systems. This process not only accelerates the wide and rapid diffusion of advanced technologies but also significantly stimulates market vitality and enhances social welfare. Therefore, digital technology is considered the core driving force for transforming traditional agriculture into a smart agriculture paradigm (Y. L. Wang & Hu, 2021).

With the advancement of today's technology, artificial intelligence has been introduced into the production management process of modern agriculture. To promote knowledge management in agricultural food systems, some scholars have established the Agricultural Knowledge Management for Innovation (AKM4I) framework in their research on innovations in agricultural food systems. AKM4I can collect data from various sources (such as agricultural fields, satellite monitoring, sensors) and use it to simulate agricultural food systems, identify

critical points in complex systems, and develop reasonable indicators. In addition, this framework enables regulatory interventions to be implemented during the process, ensuring the generation of innovative outcomes (Gardeazabal et al., 2023).

In addition, the government plays an important role in promoting the diffusion of technology in contract farming. Based on the diffusion of innovation theory, P. P. Zhao et al. (2021) conducted a survey of over 800 apple farmers in three provinces of China. They found that the diffusion of technology is influenced by the heterogeneity of farmers. When there is a significant socio-economic status difference between farmers who receive direct agricultural technology promotion services from the government and ordinary farmers, it reduces the efficiency of the diffusion of green agricultural control technologies. However, social learning among farmers plays a positive mediating role in promoting the diffusion of green agricultural control technologies. The higher the education level of farmers and the larger their social network, the more effectively they can facilitate the diffusion of green agricultural control technologies.

Research on fruit agriculture in Uruguay has shown that in developing countries, public policies from the government are the main way that agricultural technology diffusion services are provided and farmers are helped with financing. For farmers with certain resources, a mix of government assistance and private funding can better motivate them to take part in agricultural technology diffusion. However, for farmers who are not as well off, intermediary institutions are needed to help them get loans. These farmers can only get agricultural technology diffusion with this kind of help, which will help them make more money (Maffioli et al., 2013). An examination of risk factors and strategic components in beekeeping within Turkey's Igdir Province revealed that the paramount policy recommendation to protect beekeepers' income is for local governments to effectively implement agricultural extension initiatives. This facilitates the dissemination of beekeeping technical knowledge, thereby helping beekeepers understand and mitigate risks, adopt modern agricultural practices in beekeeping, and make more informed decisions regarding breeding (Karadas & Birinci, 2018).

To a certain extent, the diffusion of agricultural technologies has laid the foundation for agricultural scale expansion and sustainable. Given the important role of agricultural technology diffusion, scholars have explored the decisive factors affecting it from multiple dimensions, seeking effective methods to overcome obstacles to technology diffusion. Existing literature has revealed the significant roles of farm-level heterogeneity, agricultural scale characteristics, and social networks in facilitating the diffusion of agricultural technology. From the perspective of the external environment, previous studies have pointed out that scientific

and technological progress and government support can help promote agricultural technology diffusion. Reviewing the research on the factors influencing agricultural technology diffusion can help this study establish an important theoretical basis for a research framework that aims to improve the quality of TCMM under the “company + farmer” planting model from the perspective of technology diffusion. This study utilizes agricultural technology diffusion principles to examine their beneficial effects in the TCMM cultivation sector within a contract farming framework.

2.5 Research related to supply chain coordination

For agricultural food supply chains to achieve sustainable development, different stakeholders need to work together in a meaningful way (Dania et al., 2018). Coordination among members of the supply chain helps create shared competitive advantages, reduce conflicts, and achieve better environmental, business, and social outcomes (Papaioannou et al., 2020). Given that supply chain coordination is increasingly receiving attention from practitioners and scholars, many researchers have explored the influencing factors and consequences of supply chain coordination.

2.5.1 Factors influencing supply chain coordination

First, the rapid rise and development of emerging technologies such as the Internet of Things, big data, and blockchain have created unprecedented technological conditions for close coordination among members within the supply chain and even for the sustainable development of the entire chain. A considerable portion of existing research has focused on this and affirmed the significant positive impact these technologies have on promoting supply chain coordination.

For example, Thomson et al. (2017) examined the role of American science in promoting sustainability within agricultural supply chains. Their research indicates that coordination with the scientific community is crucial for achieving agricultural sustainability. Specifically, they explored the bridging role played by the non-profit organization developing the U.S. Commodity Crops Sustainability Initiative in facilitating dialogue among scientists, farmers, and private sector stakeholders, highlighting the vital role of scientific knowledge advancement in advancing the goals of sustainable agriculture in the United States.

The information management and control capabilities of the rice supply chain are related to grain quality and food safety. However, rice quality and safety issues continue to challenge grain quality and food safety. X. Peng et al. (2022), based on the concept of multi-chain

coordination, designed an information management and control model for the rice supply chain and applied it to a rice production enterprise in Northeast China. They utilized blockchain technology to design a "blockchain + sub-chain" multi-chain collaborative model. This multi-chain collaborative model can achieve information supervision of the rice supply chain and address the issue of real-time data interaction across various links in the supply chain. At the same time, the study applies information technology to food supply chain coordination and resource sharing, providing ideas to accelerate the digital transformation of the grain industry.

In addition, besides the agricultural sector, some scholars have also explored the potential role of blockchain technology in supply chain coordination within the information technology industry. For example, Xia et al. (2023) examined the collaborative role of blockchain technology in Lenovo, a leading company in information technology. Their study pointed out that blockchain technology changes the traditional centralized supply chain management and can provide secure, trustworthy, decentralized, and tamper-proof solutions with a consensus mechanism, playing a key role in improving operational efficiency and information sharing, ultimately enhancing supply chain coordination.

Secondly, the trust and coordination served as critical enablers in orchestrating capability amplification and sustainable transitions within the supply chain (Liao et al., 2021). Kottila and Rönni (2008) conducted an analysis of how cooperative practices within based on the study. The Finnish organic food supply chain contributed to their development. Taking two organic food supply chains as research objects, they found that trust between farmers and retailers in the supply chain is a prerequisite for promoting coordination between the two parties, while the quality of communication plays a secondary role in promoting coordination. The research suggests that improving their overall capabilities is an important way for farmers in small organic food supply chains to establish relationships with retailers.

Thirdly, the relational capital and risk management are also significant factors to drive supply chain coordination. A comprehensive analysis of collaborative dynamics within the production and processing supply chain of sugar cane in South Africa empirically delineated the collaborative relationships within this supply chain (Bezuidenhout et al., 2012). The analysis identified five critical relational quality dimensions: stability, reliability, trust density, interpersonal relationships, and communication efficiency. All the dimensions exhibited significant positive loadings in the supply chain. The deficiencies in relational capital could trigger negative risks in supply chain coordination, such as opportunism and excessive control. The empirical investigation of the sugar cane production and processing supply chains in South Africa, they developed an integrated econometric framework for decoding interorganizational

synergies. These analysis methods were helpful for promoting the development of the agricultural supply chain.

The empirical evidence from Vietnam also confirms the positive effect of relational capital and risk management in supply chain coordination. Trust and commitment constitute fundamental elements in all kinds of coordination. In other words, they are the foundation for establishing a good relationship in the supply chain coordination. Nevertheless, opportunistic behavior has undermined trust in the supply chain, and risks have hindered the fulfillment of commitments. Ho et al. (2023) investigated the factors influencing the agricultural supply chain coordination by focusing on the participating entities in the supply chain of agricultural products in the central and northern regions of Vietnam. As they noted, risks and opportunistic behavior showed a significantly negative correlation with supply chain coordination. However, collaborative risk management exerted a positive impact on the development of the supply chain. The risk-sharing contract could encourage the supply chain members to actively assume systemic risks, thus advancing the coordinated development of the supply chain (S. Cao et al., 2021).

Fourth, executives, as the actual operators of companies, can make a difference on the supply chain coordination by their features. Here's an example. From the perspective of commitments made by executives, Uddin and Akhter (2022) conducted a study on the relationship between the commitments by executives and supply chain coordination as well as sustainable business performance in the supply chain for the processing of agricultural products in Bangladesh. With a random sampling method, they made a structural equation analysis on the data collected through questionnaire surveys from 211 managers and executives of agricultural products processing enterprises. Their study indicated that commitments by middle and senior management were positively correlated with supply chain coordination, corporate environmental performance, and social performance. Supply chain coordination played an intermediary role between the commitments by middle and senior management and the corporate performance. Their study revealed that the commitments by middle and senior management were a necessary condition for achieving sustainable coordination throughout the supply network.

The leadership style influences the perceived fairness among participants in the supply chain. A study on the supply chain for the import and export of agricultural products in emerging markets explored from the perspective of executives the relationship between data-driven and adaptive leadership and agricultural sustainability. This study documented the evidence that a new leadership style contributed to trust and satisfaction among agricultural supply chain

partners and facilitated the agricultural supply chain coordination (Akhtar et al., 2016). Akhtar et al. (2017) noted in another study that the participative leadership style was more conducive than directive leadership to enhancing the effective coordination among partners in the supply chain of agricultural products.

Fifth, the role of third-party organizations in promoting the supply chain coordination cannot be neglected, allowing for the widespread imbalance of power between peasant households and companies in contract farming. From the perspective of cooperatives, Y. Yang et al. (2022) examined the positions of upstream farmers in different types of vegetable supply chains, and identified methods to enhance the sustainable coordination of vegetable supply chains. Based upon the case study of the vegetable supply chain in Vietnamese cooperatives, their findings showed that joining cooperatives was a way for Vietnamese farmers to achieve sustainable development of the vegetable supply chain. They further explored the mechanisms for stimulating the development of cooperatives. Their findings revealed that the development level of cooperative activities depended on the effective participation of peasant households in the collaborative efforts to improve the governance structure of cooperatives. The motivation of peasant households was the foundation for participation, while the management level of cooperatives constituted the institutional guarantee for their operation.

However, problems like the decreased value-added of agricultural goods and supply chain problems caused by unstable collaborative relationships make it very hard for agricultural product supply chains to grow in a high-quality way. In light of this problem, it is very important to keep coordination stable in agricultural supply chains.

For example, Huo et al. (2022) focused on supply chains primarily dealing with specialty agricultural products and led by farmers' cooperatives. They constructed a three-party evolutionary game model involving farmers' cooperatives, manufacturers, and retailers to study supply chain coordination mechanisms. Their research showed that farmers' cooperatives promote supply chain coordination by implementing strict supervision measures combined with reward and punishment mechanisms. However, rising supervision costs can inhibit the profit margins of the cooperatives. In a relatively relaxed regulatory environment, if the additional benefits brought by coordination investment significantly exceed the gains obtainable from a "free-riding" strategy, it will drive the system to evolve towards coordination. Furthermore, enhancing incremental benefits, strengthening synergistic effects, reducing collaborative input costs, and curbing free-riding gains all contribute to increasing the likelihood of achieving a Pareto-optimal state within the system. This, in turn, propels the comprehensive coordination of farmer-cooperative-led agricultural supply chains. Their research not only offers new

perspectives for theoretical discussions in the field of agricultural supply chains but also provides practical guidance for farmer cooperatives advancing collaborative supply chain management.

The existing literature has not only focused on the micro-level factors affecting supply chain coordination but has also explored the issue from a more macro perspective. For example, Papaioannou et al. (2020) examined the impact of adverse economic conditions on internal coordination within agricultural supply chains. Based on the research scenario of economic crises and the decrease in the number of agricultural cooperatives, they employed nonparametric regression and OLS regression methods to investigate how adverse economic conditions affect various types of coordination in Greek agricultural supply chains. Their study indicated that adverse economic conditions have an inverted U-shaped relationship with most forms of supply chain coordination.

Overall, current research has studied the factors influencing agricultural supply chain coordination from both macro and micro perspectives, including science and technology, trust and coordination, relational capital and risk management, characteristics of senior management, third-party organizations, and economic conditions. It is evident that collaborative governance of the supply chain is a complex area of study involving multiple levels of participants. The collaborative development of the supply chain requires the participation of multiple entities. Research on the factors influencing agricultural supply chain coordination provides theoretical support for exploring, from the perspective of supply chain coordination, the role of the "company + farmer" model in improving the quality of TCMM.

2.5.2 Economic consequences of supply chain coordination

Supply chain coordination can create a shared competitive advantage among supply chain members through information sharing, joint decision-making, and profit sharing. Essentially, it is a process of utilizing resources from all parties to achieve a win-win situation (Despoudi et al., 2018). Coordination brings benefits that individuals cannot achieve on their own, such as access to more resources. In agricultural supply chains, existing literature has explored the various benefits brought by coordination.

Matopoulos et al. (2007) explored the concept of supply chain coordination within the context of the agricultural and food industry based on the conceptual analysis. By using the case study method, they conducted depth interviews with two companies, and revealed evidence that the concept of supply chain coordination was applicable to the agricultural

products industry. Their findings provide a reference for handling the relationships between producers and processors of agricultural products in the supply chain, as well as other similar dual relationships.

A survey of Greek peach producers used the perishable characteristics of peaches to examine the important role of coordination in supply chain coordination. Despoudi et al. (2018) documented the positive returns to peach producers, benefiting from coordination within the agricultural supply chain. The analysis operationalized producer performance through two critical metrics: post-harvest loss loss ratios and suboptimal quality output percentages. By using quantile regression, they demonstrated significant inverse correlations between vertical coordination intensity and these operational inefficiencies. Notably, strategic goal alignment between agricultural cooperatives and producers emerged as the most potent predictor of quality optimization across all quantile tiers. Overall, the research by Despoudi et al. (2018) shows that cooperative practices between producers and cooperatives have a continuing positive impact on improving peach producers' performance, and that different types of coordination show different collaborative effects.

In case of contract farming, collaborative innovation could integrate the resources and knowledge of different entities (Bitzer & Bijman, 2015). In terms of collaborative innovation, Bustos and Moors (2018) examined how innovation synergy could reduce the post-harvest grain loss. They used the data on avocados imported by the Netherlands from Colombia and Mexico, for the fact that avocados were perishable and highly sensitive to the post-harvest grain loss. Innovative coordination can improve the interorganizational relationship, so that collaborative innovation participants may exchange information, coordinate incentive measures, and establish effective partnerships. They revealed that collaborative innovation could reduce the post-harvest loss of avocados and promote the sustainable development of the food supply chain.

Existing studies have also examined the impact of supply chain coordination on performance. The horizontal coordination, vertical coordination, and customer participation were three metrics for supply chain coordination. Previous literature indicated that the supply chain coordination was positively correlated with the performance of small and medium-sized agricultural enterprises (Zaridis et al., 2021). Besides, their study showed that the strategies of small and medium-sized enterprises would regulate the relationship between supply chain coordination and their business performance. Yet only a portion of the evidence supports the view that scale limitations regulate the relationship between supply chain coordination and the performance of small and medium-sized enterprises. R. Sharma et al. (2022) also found that the industry 4.0 technology could integrate the supply chain coordination and thus enhance the

effectiveness of supply chain management. This supply chain coordination can further improve the performance of sustainable agricultural supply chains.

Aggarwal and Srivastava (2016) explored the collaborative process and role of agricultural products supply chain in India. They studied how the coordination within the agricultural products supply chain contributed to lower waste and higher efficiency. A top food processing enterprise in India was chosen as the object of study. Based on the case study method, they found that supply chain coordination brought the benefits of lower waste and higher efficiency. Their further analysis revealed persistent trust deficits between suppliers and purchasers, making it difficult to establish a cooperative relationship. The study consequently advocates purchaser-led initiatives to prioritize relationship capital development while instituting performance-linked incentive frameworks across supply tiers.

The supply chain coordination can not only promote the healthy development of supply chain members, but also enhance the sustainable development of the supply chain itself. For example, from a coordination perspective, Leat and Revoredo-Giha (2013) studied the Scottish pork supply chain and tested the key risks and challenges faced by the agrifood supply chain through in-depth interviews. Better coordination among pork producers and vertical coordination among producers, processors, and retailers could weaken the supply chain vulnerability caused by risks, i.e., enhance the resilience of supply chains. As they further noted, the role of coordination in enhancing the resilience of supply chains was not only applicable to the pork production industry, but also to other agricultural food supply chains.

Supply chain coordination brings both higher economic benefits and social benefits. A study on the supply chain of handmade and agricultural products in Brazil analyzed which collective actions could generate positive social benefits. This was a case study on seven handicraft and agricultural industry supply chains in the Federal District of Brazil. The results indicated that the cooperative and collaborative models brought positive impacts to the market transactions of handicraft and agricultural products, as evidenced by the social benefits for production families (Santos & Guarnieri, 2021). Their findings confirmed that collective actions like coordination and coordination, in case of face-to-face communication, helped enhance emotional trust and improve the success rate of transactions in the supply chain of agricultural products. More directly, Imami et al. (2021) found in their survey of agricultural cooperatives in Albania that vertical coordination within the supply chain of agricultural products based on agricultural cooperatives could play a crucial role in improving food safety standards.

Besides, the literature on the environmental management of supply chains confirmed that

supply chain environmental coordination could reduce negative impacts on the environment by setting environmental goals and planning (Vachon & Klassen, 2008). From the relational and natural resource-based perspective, Barbosa and Cansino (2024) further examined the relationship between environmental coordination and performance of supply chains. They pointed out that environmental coordination between Chilean agricultural products companies would put key resources into it, such as knowledge, governance capabilities, and complementary resources. Therefore, the environmental coordination among Chilean agricultural product companies can lead to improved greenhouse gas emission management, energy management, food waste management, food safety management and water footprint management in the agricultural product supply chain. Their research is based on the environmental performance dimension and expands the positive impact of supply chain coordination from the economic aspect to the environmental aspect.

Through the literature review, some scholars systematically examined the influencing factors and consequences of agricultural supply chain coordination. For example, Dania et al. (2018) exemplified this approach through their meta-analysis of sustainable agri-food supply chains, where resource dependency theory and content analysis frameworks converge to map partnership enablers. As revealed in their research, joint efforts, sharing activities, coordination value, coordination, and stability are key factors in enhancing the evaluation and management of coordination performance in sustainable agri-food supply chains.

Baes on a systematic review of 69 literatures, Gajdić et al. (2023) mapped the core knowledge structure concerning “coordination,” “trust,” and “performance” in agri-food supply chains. After analyzing the themes, theories, and research methods of the reviewed literatures, they confirmed that coordination and trust are critical in the agricultural economy. The results of their research provide potential pathways for the effective functioning of agri-food supply chains.

Mishra et al. (2025) conducted a comprehensive review of stakeholder coordination models in the agricultural value chains of developing countries, investigating both drivers and constraints. Baes on the review, they identified market channel expansion and product quality improvement as core drivers, support from governments and non-governmental organizations as a key enabler, and divergent goals and resource shortages among stakeholders as main constraints for coordination. They further revealed that coordination priorities differed by agri-food type. The coordination in high-value cash crops focused on income generation, while that in staple foods emphasized food security. In terms of coordination results, Mishra et al. (2025) identified several benefits, including enhanced livelihoods for farmers, improved market

integration, and increased production efficiency.

In conclusion, the collaborative development of the supply chain not only increases the profits of its members but also has positive social spillover effects. For developing countries, agriculture is even more important. However, farmers are in a more disadvantaged position within the supply chain. Agricultural value chain coordination plays a vital role in increasing smallholders' participation in international value chains and enhancing their benefits from such engagement, which is particularly crucial for the sustainable development of the Chinese TCMM industry. As a typical form of contract farming, TCMM cultivation constitutes a classic agri-food supply chain. Therefore, this review of literature on the outcomes of supply chain coordination provides a theoretical foundation for this study to investigate how the "company + farmer" cultivation model enhances the quality of TCMM from a supply chain perspective.

2.6 Research related to government support

2.6.1 Government support to agricultural production

Farming is very important for farmers' livelihoods and the country's food security. Numerous nations promote local agricultural development through government support, easing farmers' financial limitations, and supplying technical assistance (Vercammen, 2007). A study on the effects of China's grain subsidy program on the area used for growing grain found that the program led to more households planting grain when they did not have enough money (Yi et al., 2015). J. F. Xu and Liao (2014) also used an economic growth model to look at how crop insurance affects agricultural output. Their documented evidence demonstrates that crop insurance fosters agricultural economic growth when insurance mechanisms are integrated into risk models. In addition, government support has a lot of good effects on farming.

First of all, government support can help improve farmers' farming technology skills. Fan et al. (2008) compared the effects of various government investments and subsidies in India on agricultural growth and poverty reduction. They confirmed that three types of government investments—agricultural research, education, and rural infrastructure development—have driven India's agricultural progress and alleviated poverty. However, during the initial stages of technology adoption, subsidies related to credit, fertilizers, and irrigation can help farmers overcome financial barriers to adopting new technologies, enabling ordinary farmers to reduce their production costs through these innovations. Different types of subsidies yield varying effects on agricultural production. Compared to direct government support, government

investments in agricultural R&D, rural infrastructure, and education represent a more long-term and effective solution to poverty alleviation.

Similarly, W. Li et al. (2019) noted in their study on factors influencing China's agricultural mechanization level that the government's agricultural machinery purchase subsidy policy and the Agricultural Mechanization Promotion Law have positively promoted China's agricultural mechanization. On one hand, government support for agricultural machinery purchases reduces farmers' acquisition costs. On the other hand, government support fosters high-quality agricultural machinery socialized services, incentivizing farmers to utilize such machinery more extensively. By elevating agricultural mechanization levels, these subsidies highlight the resulting advantages of enhanced agricultural production efficiency and reduced production costs.

Agricultural subsidies were often used to stimulate agricultural production and sustainable agricultural development. In this regard, the previous scholars have carried out many researches. Agricultural subsidies provided by the government promote sustainable agricultural development. For example, Y. H. Chen et al. (2017) explored the relationship between different types of agricultural subsidies and agricultural pollution. Specifically, they compared the different impacts of quantitative subsidies and innovation subsidies on agricultural pollution. Research has found that quantitative subsidies for agricultural output, which are the main agricultural subsidies in China, which can promote the increase of grain production and ensure food security. However, subsidies for output quantity have caused environmental pollution. In general, unlike subsidies for output quantity, innovation subsidies help alleviate agricultural pollution and promote sustainable agricultural development.

Further studies have examined the correlation between government support and agricultural sustainability from the perspective of fertilizer application. For instance, a study on Chinese rice farmers demonstrated that agricultural subsidies mitigated the adverse effects of excessive fertilizer application with technological and economies-of-scale effects (L. Guo et al., 2021). Analyzing household survey data from the Rural Economic Research Center of the Ministry of Agriculture of China from 2014 to 2018, the researchers established that every 100% increase in agricultural subsidies corresponded to a 3.4% reduction in fertilizer application, demonstrating a significant negative correlation between government support and fertilizer application. Heterogeneity analysis revealed this effect was more pronounced among peasant households with extensive rice-growing experience but limited management capacity and non-agricultural laborers. Mediation analysis further identified agricultural machinery adoption and expanded rice-growing areas as key mechanisms through which subsidies reduce fertilizer use,

highlighting the crucial role of government support in facilitating the sustainable development of agriculture.

In another study on the investment return and supply of China's green agricultural products, Xin et al. (2024) developed an evolutionary game model involving the government, agricultural cooperatives, and consumers. Their findings demonstrated that government support alleviated production cost pressures on agricultural cooperatives and stimulated green production by agricultural cooperatives, while simultaneously enhancing consumers' willingness to buy green products. However, the study cautioned that excessive subsidies could strain government finances, emphasizing that subsidy sustainability depended on the clarity of environmental benefits from green agricultural production. Therefore, they suggested that governments should establish rigorous supervision mechanisms to ensure sustainable production by subsidy-awarded cooperatives and strict quality and safety control over green agricultural products.

The government support also promotes innovation in agricultural enterprises. L. Wu et al. (2022), from a holistic industrial perspective, examined Chinese agricultural enterprises listed from 2007 to 2019, finding that government support motivated agricultural enterprises to increase R&D investment, thereby promoting their technological innovation and driving the sustainable development of agriculture. The study revealed varying effect of government support on the technological innovation across enterprises and recommended that governments should increase agricultural subsidies and strengthen supervision of subsidy utilization, while implementing differentiated support policies tailored to enterprise characteristics.

Nonetheless, agricultural subsidies do not consistently produce favorable results. To put it more simply, the effects of agricultural subsidies are very complicated. R. Zhang et al. (2021) utilized Stackelberg game theory to analyze the effectiveness of various subsidy policies. They observed that in an agricultural supply chain consisting of both high-cost and low-cost agricultural enterprises, neither a singular output subsidy scheme nor a unified environmental innovation subsidy scheme can reconcile the conflict between environmental preservation and sufficient food supply.

Pingali (2012) also said that some subsidy programs can make farming more productive, but they can also speed up the depletion of important natural resources. On the other hand, some subsidy policies that are good for the environment may change the way farming is done, which could make food security worse.

2.6.2 Government support for innovation and entrepreneurship

Innovation activities, which have positive effects on others, knowledge spillovers, high risks, and large investments, are likely to fail in the market. As a result, the government needs to step in with subsidies and other measures to make the best use of society's innovative resources (H. Wu & Hu, 2020).

Using data from applicants ranked in the U.S. Department of Energy's SBIR grant program, Howell (2017) was the first to use a quasi-natural experiment to evaluate the role of government support in promoting innovation. Their study found that companies receiving government support early were nearly twice as likely to subsequently secure venture capital, while also showing significant increases in patent applications and revenue. Moreover, this effect was more pronounced in the subsample of companies facing more severe financing constraints. Interestingly, the effect of the subsidies may not be due to the government funding serving as a form of "certification" of firm quality (for instance, a certification effect), but primarily because of the tangible financial support—these funds actually helped companies turn their technology into prototype products.

A study from China examines the impact of external government support and internal absorptive capacity synergies on corporate green technological innovation. This research reveals that government support combined with different types of internal absorptive capacity synergies produce varying effects on green technological innovation. Given that unabsorbed capacity has limited control over available resources, this in turn incentivizes firms to pursue synergies. Consequently, government support synergized with unabsorbed capacity is more effective at achieving resource sharing and driving corporate green technological innovation. However, government support combined with absorptive redundancy resources suppresses corporate green technology innovation (H. Wu & Hu, 2020). Since companies' resource mobilization and allocation are governed by equity concentration, the study also examined the moderating role of equity concentration. Their research highlights that both excessive dispersion and concentration of equity ownership hinder the deployment of government support and unabsorbed redundancy. The former impedes effective decision-making, while the latter may give rise to large shareholder asset stripping, jeopardizing corporate health. Moderate equity concentration maximizes shareholder value. Under such conditions, the reconfiguration of government support and unabsorbed redundancy can generate greater innovation incentives.

Government support not only supports corporate innovation by alleviating financing constraints but also aids in financing startups. Since the value generated by startups is often

unobservable to potential investors, they frequently face severe financing constraints (Baum et al., 2000). Government support does yield positive outcomes for entrepreneurial firms, yet they simultaneously imposes numerous restrictions on subsidized enterprises. Conti (2018), studying Israeli startups, found that when the government eased restrictions on subsidy applications for startups, government R&D subsidies improved startup survival rates. Furthermore, government R&D subsidies enhanced startups' ability to attract external capital and their overall innovation capacity.

Similarly, an empirical study in China examined how government support promotes the growth of startups in the clean energy industry. H. Peng and Liu (2018) examined the moderating effects of ex-ante and ex-post government support on the correlation between R&D investment and startup growth. They found that R&D investment did not exhibit a significant lag effect on the growth of startups. However, prior government support negatively moderated the relationship between R&D investment and startup growth, whereas subsequent government support positively moderated this relationship.

But giving out more than one subsidy at a time can have confusing effects. J. Y. Chen et al. (2019) explored how government support affects supply chains' ability to come up with new ideas that are good for the environment. They determined that when manufacturers and retailers collaborate through joint ventures within the supply chain, the government should refrain from concurrently implementing both unit production subsidies and innovation effort subsidies. This is because the only way for both types of subsidies to work together to get the supply chain to work together in the best way and boost innovation is if R&D spending raises production costs.

L. Wu et al. (2022), based on a multi-dimensional perspective encompassing the entire agricultural, forestry, animal husbandry, and fishery industry chain as well as processing, manufacturing, and circulation services, took listed agricultural companies from 2007 to 2019 as the research objects to empirically examine the impact mechanism of government support on technological innovation in agricultural enterprises. By conducting analyses using fixed effects models and mediation effect models, they found that government support has a significant promoting effect on the growth of agricultural enterprises. Among these, R&D expenditure plays a core mediating role in the process of technological innovation within enterprises. However, the effect of government support on technological innovation shows structural differences, specifically manifested in the heterogeneity across three dimensions: industry characteristics, ownership types, and enterprise scale. Therefore, they recommend that the government, while maintaining the level of subsidies, implement differentiated subsidy

strategies and strengthen the supervision of fund usage to systematically enhance the effectiveness of agricultural technological innovation policies.

2.6.3 Government support for green production

Green production has positive effects on the outside world, which may make companies less likely to use environmentally friendly methods of production. In these situations, governments are very important for encouraging green production and the use of green technologies. Based on this basic idea, many researchers have looked into government support for green production.

Ringel et al. (2016) estimated the economic effects of putting the German government's energy efficiency policies into action. They said that the National Action Plan for Energy Efficiency (NAPE) and the Action Plan for Climate Protection (APC 2020) would help Germany's energy, environment, and economy grow in the short term. Germany is expected to save 241.2 PJ of final energy and 394.2 PJ of primary energy every year by 2020. At the same time, Germany's greenhouse gas emissions would drop by 24.2 million tons. Green energy policies could also help people and businesses save between €90 and €100 billion on fuel costs and bring in at least €70 to €80 billion in new investments. These investments could then raise Germany's GDP by 0.4% to 2.6% and create about 48,000 full-time jobs.

A study examining the influence of government support on China's photovoltaic industry reveals that subsidies impact enterprises differently at distinct stages of development (Xiong & Yang, 2016). Through empirical analysis, they determined that government support has effectively stimulated the expansion of China's photovoltaic industry and cultivated a cohort of exemplary enterprises. But too many subsidies have caused the photovoltaic industry to have too many products, which wastes resources. The government should change its subsidy policies based on the different stages of growth of businesses, stopping and removing subsidies when they are no longer needed. Only then will subsidized PV companies be able to slowly stop relying on government money and do better in the market.

Beyond direct subsidies, tax policies can also be used to encourage green production. For example, Krass et al. (2013) investigated the role of environmental taxes in reducing environmental pollution and motivating the choice of greener technologies by profit-maximizing enterprises. They found that enterprises responded differently to varying levels of environmental taxes. While moderate environmental taxes initially motivated a switch to greener technologies, excessively high tax rates could reduce corporate revenues to a point where they could not cover the costs of advanced green technologies. In such cases, despite of

environmental taxes, enterprises tended to choose cheaper and less environmentally friendly technologies rather than continuing to invest in emission reduction technologies. To address this limitation, the researchers argued that governments could supplement environmental taxes with fixed-cost subsidies and consumer rebates to offset the welfare losses caused by excessively high environmental taxes.

Similarly, X. Yang et al. (2019) employed panel threshold regression modeling using data on 92 Chinese listed renewable energy enterprises, identifying a significant positive threshold effect of government support on renewable energy investment. The researchers further analyzed the heterogeneous impacts of subsidy types and enterprise scales on this effect. The results revealed that government support had stronger promotion effect when energy consumption intensity and bank credit levels were higher, and economic development levels remained below certain thresholds. Based on these findings, the researchers recommended that governments should strengthen policy support to implement differentiated subsidy strategies with particular emphasis on micro, small and medium-sized enterprises and guide large-scale enterprises to expand renewable energy investments, especially in regions undergoing economically challenging energy transitions.

Where conflicts arise between environmental protection and economic development, well-designed government intervention can help reconcile these priorities. Joo et al. (2018) demonstrated that in South Korea, government support encouraged manufacturing enterprises to comply with international export standards and enhance their global market performance. Specifically, the study identified four forms of government support: facilitating the collection and analysis of environmental information, offering environment-related education and training, supporting environmental certification, and supporting environmental protection R&D. These measures collectively enhanced the environmental and technological innovation capabilities of South Korean manufacturing companies. Further, these enhanced capabilities have effectively improved the company's environmental performance and export performance.

Electric vehicles are also a typical industry that receives government support. In order to promote the transformation of the automobile industry towards new energy and intelligence, the government has provided corresponding policy subsidies. Chemama et al. (2019) studied how the government's commitment to fixed or flexible subsidy policies affects manufacturers' green production decision-making. They pointed out that in a two-period game environment under uncertain demand, when the government commits to maintaining stable policies, it can motivate suppliers to expand production scale early on based on clear expectations.

Y. Li et al. (2020) investigated three government subsidy schemes—Green Non-Subsidization (GNS), Green Product Subsidy (GPS), and Green Innovation Subsidy (GIS)—to see how they affected different people in the supply chain and which one would be best for encouraging more green development. They said that giving green subsidies is not always the best thing for the government to do. The kind of subsidy that companies get depends on how much it costs to come up with new green ideas.

Implementing no subsidies (GNS) is the better strategy when the costs of green innovation are very low or when both the costs of green innovation and the costs of making green products stay high while the environmental benefits are small. In most other situations, though, using either GPS or GIS can improve social welfare. In situations where green innovation costs are high and innovations that significantly lower variable production costs for green products are present, GIS directly alleviates corporate innovation cost pressures; however, GPS still outperforms GIS. But if the main goal is to make subsidies work better, GIS is always better than GPS.

Bigerna et al. (2019) examined the impact of fixed-form government support on firms' optimal investment decision-making concerning timing and scale amid market demand uncertainty. Using research scenarios from Italy's EU policy-driven renewable energy deployment strategy, they discovered that increased government support prompts firms to invest in renewable energy capacity sooner, albeit with reduced investment capacities. They made models to figure out the best levels of government support to reach the EU's green energy capacity expansion goals for 2020 and 2035.

Another study explored the moderating role of government support in the relationship between country risk and the performance of renewable energy companies (W. W. Zhang et al., 2022). Using listed renewable energy companies in China's A-share Shanghai and Shenzhen markets as the sample, their research indicated that economic and financial risks are negatively correlated with the performance of renewable energy companies, while political and composite risks are positively correlated with performance. Subsidies have a negative moderating effect on the relationship between national risk and the performance of renewable energy companies. They emphasize that when planning economic policies for the renewable energy sector, the Chinese government needs to comprehensively consider the interactive effects of national risk and government support on corporate performance, and pay attention to the potentially different impacts these factors may have on enterprises of different ownership types.

2.6.4 Government support for remanufacturing

Remanufacturing can improve resource utilization in certain industries and reduce costs. In addition, remanufacturing can also play an environmental role by alleviating the negative impact on the environment (Mitra & Webster, 2008). For example, Y. Zhou et al. (2021) examined how government support influences the strategic choices of companies and individuals in the recycling and utilization of agricultural waste. They constructed a tripartite evolutionary game model involving government, companies, and individuals, analyzing decision-making interaction mechanisms from a stakeholder perspective. Government support can be approximated as a game-theoretic process. Within this framework, the purpose of government support is to balance the objectives of the government, individuals, and companies. Y. Zhou et al. (2021) noted that government support reduces costs for both companies and individuals, incentivizing active participation in agricultural waste recovery and treatment. However, government support constitutes a complex and dynamic process; implementing recovery subsidies solely for enterprises or farmers is unlikely to achieve the desired outcomes.

A study on low-carbon e-commerce closed-loop supply chains explored the impact of government support and remanufacturers' altruistic preferences on decision-making. By encouraging remanufacturers through subsidies and carbon taxes, the government reduces their investment costs and risks, promotes waste recycling, and enhances the overall efficiency of low-carbon, environmentally friendly closed-loop supply chains (Y. Wang et al., 2020). Leading companies with altruistic behavior toward subordinate enterprises can pay attention to the overall benefits of the e-commerce platform, thereby increasing the platform's overall profits and achieving an increase in total social welfare. Their research suggests that policy-making should consider the synergistic effect of economic incentives and ethical guidance, balancing environmental objectives with the sustainable operation of companies.

Government support exerts varying impacts on different types of remanufacturers. D. Feng et al. (2021) examined secondary markets encompassing both remanufacturing and refurbishing enterprises, analyzing how government support influences equilibrium strategies and supply chain participants. Government support alleviates the financial and technological constraints faced by companies during remanufacturing. Utilizing the highly competitive remanufacturing market for end-of-life vehicle parts, D. Feng et al. (2021) revealed the effects of government support on supply chain members under different remanufacturing models. Remanufacturing subsidies lower the threshold for participating firms to engage in remanufacturing and improve the marginal conditions for remanufacturing. For original remanufacturers, receiving

government support incentivizes increased production of remanufactured products but hinders the production and development of new products, thereby reducing their market share. For independent remanufacturers, government support shows limited effects when remanufacturing costs are low. However, as remanufacturing costs rise, subsidies can stimulate increased output of remanufactured products. Notably, this rise in remanufactured product volume is accompanied by a decline in quality. Their research, through a systematic analysis of the differentiated impact of subsidy policies under different remanufacturing models and cost structures, provides an important decision-making basis for the government to formulate precise support policies for the remanufacturing industry.

Government support for the remanufacturing of old farm equipment also makes it less difficult for farm equipment to be used in a circular way. L. Zhou et al. (2023) found that when the market supply of remanufactured products is excessive, the lack of economic incentives can inhibit the recycling of discarded agricultural machinery. At this time, government support can serve as a new economic incentive to ensure the normal recycling of discarded agricultural machinery. Specifically, the government can promote the sustainable resource utilization of agricultural machinery by establishing a price support mechanism for the recycling process, implementing relevant tax incentives, and setting up special research and development funding programs.

2.6.5 Government support to consumers

In many poor rural areas of developing countries, governments use consumer subsidy policies to help residents. Governments also give consumers shopping subsidies to encourage economic growth and the upgrading of industries. For example, in 2025, the Chinese government has allocated 300 billion yuan in ultra-long-term special government bonds specifically to support the replacement of old consumer goods with new ones. The following is related research on government support for consumers:

J. J. Yu et al. (2018) constructed an overall analytical model to examine how the government uses special budgets to formulate subsidy policies to improve consumer welfare in rural areas. The government, manufacturers, and consumers were included in this model to study the strategic interactions among them. They pointed out that when products have set prices, subsidizing only consumers is the optimal subsidy plan. However, when products do not have set prices, subsidizing only manufacturers is the best choice. In addition, competition among manufacturers can improve consumer welfare. Therefore, the government should

introduce multiple competitive and differentiated manufacturers into the subsidy program, such as prioritizing large manufacturers with substantial market size and ample production capacity. Regarding the household appliance subsidy program for rural Chinese families, J. J. Yu et al. (2018) suggest that the Chinese government should only subsidize standard products such as televisions and mobile phones, as well as customized products designed by manufacturers specifically for the rural market, in order to prevent welfare loss.

With people's increasingly frequent use of automobiles, the issue of car energy has received widespread attention. To save energy and reduce carbon emissions, many governments offer substantial subsidies to consumers who purchase electric vehicles. Scholars have conducted related research on car subsidies, focusing on reducing air pollution from emissions of traditional fuel vehicles and promoting environmental development.

J. Huang et al. (2013) examined the impact of government support on the fuel vehicle supply chain and the fuel vehicle versus electric vehicle supply chain. They demonstrated that incentive-based subsidy measures help enhance overall social welfare, expand the sales scale of power enterprises, and reduce negative environmental impacts. Furthermore, increasing the number of service outlets and charging facilities can further amplify the positive effects of this subsidy policy on the power market while mitigating its adverse effects on the fuel vehicle market. In terms of implementation methods, incentive policies demonstrated greater effectiveness than centralized controls in promoting the development of electric vehicle enterprises and environmental protection.

Another study tested the impact of government-provided subsidy incentives or price discount incentives on consumer electric vehicle purchases and social welfare from the perspective of a non-cooperative game between the government and manufacturers (Shao et al., 2017). Within a duopoly market structure, heightened consumer awareness of low-carbon initiatives may paradoxically suppress electric vehicle adoption under certain conditions. This counterintuitive phenomenon primarily stems from the resulting increase in retail prices. Governments must consequently adjust their policy interventions. Specifically, when unit production costs are low and government support are high, the retail price of electric vehicles rises rapidly as low-carbon awareness increases, thereby weakening market demand. This indicates manufacturers are exploiting heightened consumer environmental awareness to raise prices. Government support can reduce consumer purchase costs in such scenarios, ultimately driving the adoption and proliferation of electric vehicles.

Existing literature provides multidimensional theoretical support and mechanism references for understanding the role of government support in this study. In the field of

agricultural production, research indicates that government support directly enhances production efficiency and standardization by lowering the barriers to technology adoption and optimizing resource allocation. For example, whole-industry chain subsidies have been shown to promote agricultural enterprises, providing a theoretical basis for analyzing government intervention in the planting stage under the "company + farmer" model. In studies on green innovation and remanufacturing, government support has been shown to have a "double-edged sword" effect: it can incentivize environmentally friendly behaviors through subsidies, but may also lead to resource misallocation or distorted incentives if the mechanisms are improperly designed. This finding suggests that this study needs to pay attention to the potential nonlinear regulatory characteristics of government support in improving the quality of TCMM.

However, existing research has largely focused on macro-level agricultural output or industrial products, lacking an exploration of the quality formation mechanisms of TCMM—a special industry that simultaneously possesses the attributes of agricultural products, pharmaceutical standards, and ecological constraints. In particular, there is a shortage of in-depth analysis on how government support moderates the paths of "multi-actor coordination" (such as company-farmer interactions) and "multi-dimensional quality attributes" (such as component content, safety, and authenticity). This study addresses this theoretical gap by drawing on the shared insights from existing literature regarding the mechanisms of government support in different contexts and extending them to the complex system of quality governance in TCMM. In doing so, it aims to build a more explanatory theoretical framework and provide empirical evidence for the precise design and context-specific adaptation of policy tools.

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Chapter 3: Conceptual Model and Research Hypotheses

As a vital agricultural product, TCMM is influenced by various factors, including climate change, soil conditions, farmers' resource endowments, and market dynamics (Lv et al., 2024). Considering that the "company + farmer" structure is a common model in herbal cultivation, this study investigates how this organizational model impacts product quality. Through contract farming, coordination between companies and farmers can facilitate technological and efficiency improvements (Gong et al., 2019; Khan et al., 2019). Specifically, technological application and organizational structure are identified as critical determinants of quality in TCMM planting. Consequently, this research concentrates on the technological and organizational dimensions to identify the key factors affecting the quality of TCMM.

At the technical level, companies usually have more scientific cultivation techniques than farmers (Gramzow et al., 2018). The flow of cultivation technology from companies to farmers due to contract farming may be an important reason for the final quality improvement. Combining the two subjects in the "company + farmer" model, this study chose to examine the roles of farmers and companies in the diffusion of TCMM cultivation technology from the dimensions of technology adoption and technology sharing.

In the organizational dimension, the imbalance of voice between companies and farmers in the "company + farmer" model is a significant factor driving farmers to withdraw from contract farming (Q. Wang et al., 2013). Conversely, coordinated development between companies and farmers can contribute to the sustainability of the contract farming model (Bogetoft & Olesen, 2002). Furthermore, the fact that farmers are often at an information disadvantage and lack trust in the company undermines the stability of contract farming (Ruml & Qaim, 2021). Therefore, from the perspective of supply chain quality coordination, this study examines the effects of information coordination and decision-making coordination on the quality of TCMM.

Furthermore, given the indispensable role of the government—particularly in China—in the development of the TCMM industry (W. Y. Wang et al., 2021), this study further explores the impact of government support on the quality improvement of TCMM.

Considering the current challenges in the quality development of TCMM and the actual practices of the "company + farmer" contract farming model, this study constructs a conceptual model. Specifically, in order to explore the impact "company + farmer" model on the quality of TCMM, this study uses the TOE theoretical framework proposed by Tornatzky and Fleischer (1990) to analyze the influencing factors within the model. From the perspective of technical

factors, the cultivation techniques used directly affect the TCMM quality. From the perspective of organizational factors, in the supply chain structure of "company + farmer" model, the coordination and coordination between companies and farmers are key to the quality control. From the perspective of environmental factors, within the conventional "company + farmer" model of TCMM enterprises, both government supervision and policy support can affect the standardized TCMM cultivation, which affects the TCMM quality in turn. This structured analysis provides a theoretical base for understanding and improving the TCMM quality management.

Based on the TOE framework, this study constructed a three-dimensional model to investigate factors influencing the quality of TCMM in the "company + farmer" cultivation model adopted by TCMM companies. It systematically clarifies the interdependent relationships among agricultural technology, supply chain quality coordination, and government support in attaining sustainable quality enhancement of TCMM within the "company + farmer" model. Figure 3.1 shows the research framework of this study in detail. In the next section, this study will elaborate on the theoretical model of quality enhancement of TCMM.

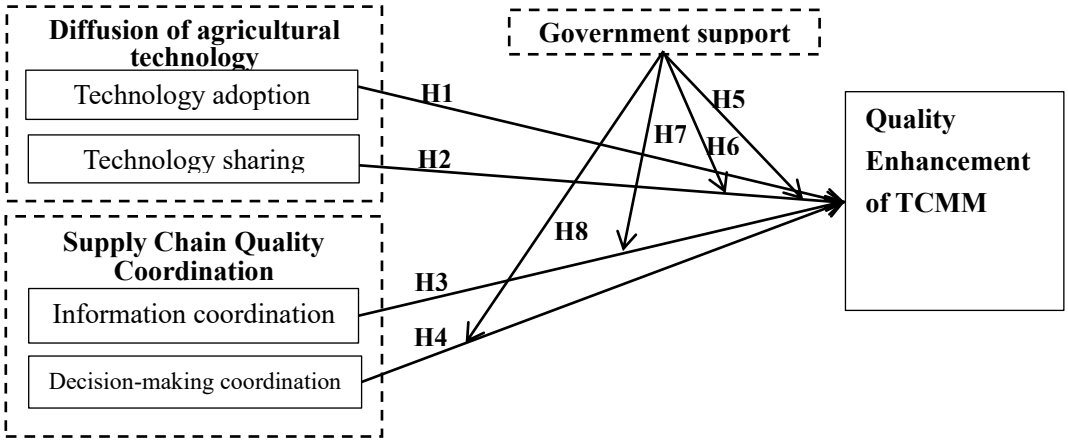


Figure 3.1 Theoretical model for improving the quality of TCMM in the "company + farmer" model of TCMM companies

3.1 Agricultural technology diffusion perspective

Tornatzky and Fleischer (1990) indicated that technological factors have a direct effect on output quality by changing the way things are made. In the cultivation of TCMM, the diffusion and adoption of technology function as fundamental technological innovation variables, influencing the stability of active ingredients and the extent of pesticide residue management in TCMM.

The quality of TCMM has a direct effect on how well clinical treatments work, which in turn affects the physical and mental health of patients (Song et al., 2013). It is important and urgent to look into how the spread of TCMM cultivation techniques affects the quality of herbs.

3.1.1 The impact of technology adoption on the quality of TCMM

The theory of agricultural technology diffusion posits that the adoption of new technologies by farmers is the primary catalyst for enhancements in agricultural product quality (Rogers, 2003). Cultivation techniques are very important for the quality of TCMM (Lv et al., 2024). The quality of field management techniques used on medicinal plants from planting to harvest has a direct effect on how well they grow and develop. Good farming practices enable medicinal plants build up more active ingredients. Seed germination rates at the sowing stage determine the yields that follow. Studies show that treatments before germination can help medicinal crops germinate better because they are dormant (Müller et al., 2019).

For example, gibberellic acid treatment can significantly increase the germination rate of tulip seeds, while an overly thick covering layer can reduce the number of seedlings (W. Zhang et al., 2020). During the growth stage, different medicinal plants have different requirements for planting and covering methods. Previous studies have found that at medium density, Anoectochilus formosanus can accumulate more biomass and ginsenoside content (H. Liu et al., 2021). In addition, using chemical herbicides to control weeds may pose a risk of herbicide residues in medicinal plants (Chandra, 1994). Therefore, for some medicinal crops, manual weeding may be a better approach.

Fertilization is an important job for farmers. A lot of research shows that different medicinal plants need different ways of fertilizing. For example, nitrogen fertilizers can boost the levels of nitrogen-containing secondary metabolites in TCMM, which improves the quality of medicinal plants (Ge et al., 2021). Nonetheless, the application of excessive nitrogen fertilizer diminishes biomass and saponin accumulation in Panax notoginseng (Cun et al., 2023). Different ways of processing and storing medicinal herbs can also change their quality (S. D. Lee et al., 2014). Overall, high-quality TCMM require systematic professional cultivation techniques from sowing to storage.

Due to issues such as confused germplasm resources and improper field management during cultivation, medicinal plants grown under artificial conditions face problems including low levels of active ingredients and excessive heavy metal content. Improving medicinal plant cultivation technology is a key means to enhance the quality of TCMM. However, farmers'

decision-making to adopt cultivation technologies is influenced by production costs, market conditions, their own resource endowments, and their awareness levels (W. Liu et al., 2023; Tey & Brindal, 2012). Moreover, technology adoption confronts compatibility dilemmas: small-scale farmers have insufficient capacity to absorb complex technologies (Sanogo et al., 2023). From the supply chain perspective in the TOE framework, companies can reduce adoption thresholds and improve the effectiveness of technology adoption by providing farmers with technology packages (seeds-fertilizers-training) through contractual relationships. For example, a survey of 4,520 farm households in the upper and middle reaches of the Yellow River found that agricultural industrial organizations can promote farmers' adoption of low-carbon production technologies through incentive effects and the constraints of contractual norms (Y. X. Huang et al., 2025).

Under the "company + farmer" model, the contractual relationship between companies and farmers clarifies the rights and obligations of both parties on the one hand. Through contracts, companies' obligations to provide advanced cultivation technologies and regular training to farmers are specified, which strengthens farmers' trust in the company's technical support (Pham et al., 2021). This continuous technology sharing deepens farmers' understanding of cultivation technologies and makes them aware of the importance of technology for improving the yield and quality of TCMM. In other words, the contractual relationship between companies and farmers reduces farmers' perceived risk of uncertainty in technology adoption and enhances their perceived usefulness of the technologies shared by companies (Caffaro et al., 2020).

On the other hand, the company can motivate farmers to better learn and master cultivation techniques through material rewards and production and sales guarantees (W. Zhang et al., 2023). For example, the company regularly provides contract farmers with planting training and technical guidance to help them better learn and apply the techniques. Farmers' perceived ease of use of the technology gradually increases, which in turn promotes their willingness to adopt the cultivation techniques (Zheng et al., 2019). In short, in the "company + farmer" model, the contracts and incentives provided by the company promote farmers' adoption of technology, thereby helping to improve the quality of TCMM. Therefore, this study proposes the following hypothesis:

H1: The adoption of the company's cultivation techniques by farmers exerts a positive influence on the quality of TCMM.

3.1.2 The impact of technology sharing on the quality of TCMM

Technology is an important part of a business's survival and growth. A company can create its own competitive edge by keeping its technology exclusive in the market (Sköld & Karlsson, 2012). Thus, keeping technology secret is essential. Supply chains are always changing, which has brought upstream and downstream partners closer together. A growing number of investigations are now looking at how well the whole supply chain works (Pagell & Shevchenko, 2014). Technology sharing among supply chain members is becoming more common as a way to make supply chains more sustainable.

Prior studies have demonstrated that technology sharing within supply chains enhances organizational performance (Rajabion et al., 2019). Lawson et al. (2009) conducted a survey of 111 manufacturing organizations in the UK and discovered that inter-organizational technology sharing enhanced buyers' product development performance, subsequently improving financial performance. Ersoy et al. (2022) also showed that sharing technology in the meat industry helps green business growth in circular food supply chains. More directly, M. Ma et al. (2024) demonstrated that sharing technology between smart and traditional vehicles improves business performance and helps the market grow.

Technology sharing within supply chains can also benefit other industries. In the field of TCMM cultivation, under the "company + farmer" model, companies and farmers are crucial in the TCMM supply chain. To improve their performance and gain a competitive advantage in the TCMM supply market, companies are motivated to share technologies with farmers (Yuen & Lam, 2024). In turn, these advanced agricultural technologies were learned and employed by farmers in TCMM cultivation, ultimately improving the TCMM quality (Gong et al., 2019). Under the "company + farmer" model, companies establish closer relationship with farmers, becoming more willing to share technologies (D. Yu & Zhou, 2017). The community of shared interests formed between the two parties often bring companies with more benefits than the costs incurred by technology sharing. Meanwhile, farmers can access more advanced technologies, thereby enhancing TCMM cultivation techniques and product quality (Mtega & Msungu, 2013). In addition, online and offline communication platforms are developed under this model, enabling companies to promptly provide guidance to farmers in technology application and prevent plant diseases and pests in TCMM cultivation. Based on the above analysis, we propose the following hypothesis:

H2: The company's sharing of agricultural techniques with farmers positively influences the quality of TCMM.

3.2 Supply chain quality coordination perspective

In the TOE framework, coordinating the supply chain within an organization is vital for improving its performance (Chu et al., 2025). Good organizational conditions can make governance work more effectively (Wen & Jiang, 2023). This study asserts that in the TCMM cultivation sector, coordination among supply chain segments profoundly influences TCMM quality. Consequently, this section emphasizes the organizational coordination perspective within the TOE framework to investigate the role of information and decision-making coordination between companies and farmers for enhancing farmers' TCMM quality.

3.2.1 The impact of information coordination on the quality of TCMM

At present, numerous scholars have investigated the influence of information coordination on supply chain performance (Hussain & Saber, 2012; Moinzadeh, 2002). Sharing information throughout the supply chain can be very beneficial (H. L. Lee et al., 2000). Sharing information between retail platforms and manufacturers in the supply chain helps suppliers better understand what customers want, which makes manufacturers spend more on product quality (Shin & Zeevi, 2024). Moreover, information sharing, as a crucial element in supply chain management systems, can confer enduring competitive advantages to organizations (S. Li & Lin, 2006). A smooth supply chain can give each node the same, up-to-date marketing data (Childerhouse & Towill, 2003). Some researchers discovered that blockchain-based agricultural data sharing can dismantle the conventional seclusion of agricultural information and facilitate the sustainable development of the ecosystem (Zhu & Li, 2021). In particular, sharing information helps researchers and industry experts quickly understand the problems that farmers face, such as helping them get rid of cattle tick fever and fight citrus greening (Kharel et al., 2022).

The "company + farmer" model in TCMM cultivation can help establish trust between companies and farmers through contractual relationships. As a prerequisite for coordination, trust brings numerous benefits (Kottila & Rönni, 2008). On the one hand, it can alleviate farmers' concerns about the abuse of planting data and the damage to their own interests (Wiseman et al., 2019). On the other hand, the establishment of contractual relationship can reduce the data leakage risk of companies (Boasiako & Keefe, 2021). Trust ensures timely communication and exchange between companies and farmers regarding high-quality medicinal material varieties, planting plans, market demand, and medicinal material prices

(Huda, 2024). This can accelerate the information flow in the supply chain and mitigate the information asymmetry between companies and farmers (Mardenli et al., 2025). Companies and farmers can also better reach consensus and collaborate in production, harvesting, and processing links. This means that the "company + farmer" model can reduce quality problems arising from information asymmetry.

In the long term, information coordination between companies and farmers will be able to enhance their core competitiveness in the herbal medicine supply market (S. Li & Lin, 2006). In addition, improving information transparency is an effective solution to address product quality and safety issues (H. Feng et al., 2020). Information coordination between companies and farmers also enables companies to supervise the farming process, providing timely feedback to resolve problems such as pests, diseases, or improper fertilization encountered during the cultivation of medicinal herbs, ultimately promoting the improvement of TCMM quality. Based on the above analysis, this study proposes the following hypothesis:

H3: Information coordination within supply chain quality coordination positively influences the quality of TCMM.

3.2.2 The impact of decision-making coordination on the quality of TCMM

Ramanathan and Gunasekaran (2014) claim that successful collaborative decision-making between supply chain partners can make it more probable that they will work together again in the future and build long-term cooperative relationships. Furthermore, evidence from food networks demonstrates that coordination in supply chain decision-making can foster multi-party coordination throughout the entire supply chain network, ultimately improving the sustainability of delivered products (Allaoui et al., 2019). Evidence from the agricultural sector suggests the influence of supply chain coordination on the quality of agricultural products.

For example, a study that used a unique dataset from Greek peach producers found that high levels of coordination led to less food waste after harvest and a smaller percentage of low-quality peaches (Despoudi et al., 2018). Another scholar's study on decision-making in fresh agricultural product supply chains showed that contracts that share profits between manufacturers and retailers eased worries about fairness. Under this kind of coordination, the freshness preservation decisions of manufacturers and retailers regarding agricultural products can enable both parties to achieve better utility (B. Yan et al., 2020).

Similarly, in the field of TCMM cultivation, the positive effects of collaborative decision-making are also reflected in the coordination between companies and farmers. Under the

"company + farmer" cultivation model, TCMM production companies and farmers within the same supply chain can participate in overall strategic planning from different perspectives, leveraging their abilities at various levels to improve the quality of TCMM. Farmers and businesses can use each other's resources and enjoy the benefits that come with them. This coordination in the supply chain makes collaborative advantages stronger, which in turn helps both companies and farmers do better (M. Cao & Zhang, 2011).

Specifically, high-quality TCMM cultivation orders can closely match what the market requires for different types of TCMM and quickly adapt to changes in what the market requires. Farmers and companies jointly formulate acceptance standards for TCMM, discuss order prices, order quantities, settlement methods and formalize them through contracts, which alleviates information asymmetry between them and can enhance mutual trust. At the same time, especially for farmers, participation in decision-making regarding planting orders and harvesting increases their sense of fairness in decision-making and willingness to execute (Vamuloh et al., 2020). This increase in mutual trust brought about by decision-making coordination between companies and farmers, along with the enhancement of farmers' sense of fairness and execution willingness, in turn improves the quality of medicinal herbs and enhances company performance (Ramanathan & Gunasekaran, 2014). Therefore, decision-making coordination can bring benefits to both companies and farmers, motivating them to put in more effort to improve the quality of medicinal herbs. Based on the above analysis, we propose the following hypothesis:

H4: Decision-making coordination within supply chain quality coordination positively influences the quality of TCMM.

3.3 Government-supported adjustment perspective

Government support refers to the tangible and intangible resources actively provided by the government, such as financial subsidies, tax reductions, knowledge, and social capital (Stephan et al., 2015). As an important external factor, government support plays a significant role in various areas, including social entrepreneurship (Stephan et al., 2015), innovation output (Kwan & Chiu, 2015), and the promotion of science and technology development (Shu et al., 2015). To promote the development of the TCMM planting industry, the Chinese government has provided a series of supports. Therefore, this study also focuses on the moderating role of government support in the impact of various factors on the quality of TCMM.

3.3.1 Moderating effect of government support on technology adoption for improving TCMM quality

Although the share of agriculture in GDP has gradually shrunk, the agriculture remains an important foundation for the development of other industries (S. Yao, 2000). The governments currently support agricultural development by providing financial subsidies or advisory assistance (Alizamir et al., 2019; Mastenbroek et al., 2021). These supportive measures also effectively facilitate farmers' technology adoption. The existing research demonstrated that governments assisted farmers in adopting agricultural technologies by providing them with essential product information to overcome knowledge barriers (Mastenbroek et al., 2021), In addition, the government can also provide credit channels to farmers in economically underdeveloped areas to help the financial constraints and help farmers adopt new technologies (Mukherjee, 2020).

The medicinal value of the TCMM has been validated in thousands of years of practice (Chan, 2016). In order to promote the development of the TCMM industry, the government has successively introduced a series of subsidies and support policies (W. Y. Wang et al., 2021). The financial and technical needs of TCMM farmers and lower the threshold for adopting new technologies. These measures effectively lowered production costs for farmers, making them more willing to adopt advanced cultivation technologies (Fan et al., 2008). For example, relevant policy supports and subsidies such as the Industrial Plan for Traditional Chinese Medicinal Materials and the Good Agricultural Practice of Traditional Chinese Medicinal Materials have promoted the progress of TCMM cultivation technologies, ultimately contributing to the improvement of TCMM quality. Therefore, we propose the following hypothesis:

H5: Government support positively moderates the impact of agricultural technology adoption on the quality of TCMM.

3.3.2 Moderating effect of government support on technology sharing for improving TCMM quality

The company shares technology with farmers, such as standardized cultivation, integrated pest and disease management, harvesting and processing, and quality control, which can help alleviate farmers' technical deficiencies and thereby improve the quality of medicinal materials (Lv et al., 2024). However, differences among farmers in terms of finances, technology, and awareness may hinder the sharing of technology between the company and farmers

(Mastenbroek et al., 2021). Government support can reduce the cost for farmers to learn these technologies through investments in training, subsidies, public testing, and traceability platforms.

In addition, for farmers, having the government act as an authoritative third-party guarantee can enhance their trust in the company's technical solutions and strengthen their perception of the improvement in the quality of TCMM brought about by technology sharing (Eaton & Shepherd, 2001; R Zhang et al., 2021). Finally, for companies, the government amplifies the incentive effect of technology sharing through standard subsidies, insurance, and replacement of subsidies with rewards (He et al., 2023), increasing the benefits of quality improvement in TCMM brought about by technology and enhancing the willingness of companies and farmers to share technology (Xue et al., 2022). Therefore, based on the above analysis, this research proposes the following research hypotheses:

H6: Government support positively moderates the impact of agricultural technology sharing on the quality of TCMM.

3.3.3 Moderating effect of government support on information coordination for improving TCMM quality

Scholars have confirmed that collaborating together to share information can help reduce information asymmetry and boost the performance of organizations in supply chains (Hussain & Saber, 2012; Moinzadeh, 2002). The government can play two roles: it can give companies and farmers resources and set rules for them to follow (Patanakul & Pinto, 2014). This can help improve the quality of TCMM by making the coordination between companies and farmers work better. In particular, government support can work in three ways.

First, the government can promote information about high-quality varieties of relevant TCMM through subsidies and publicity campaigns (Bian et al., 2022), thereby enhancing farmers' confidence in the high-quality seeds provided by the company. Second, the government can set clear quality standards for medicinal herbs through pharmacopoeia regulations, quality certifications, and strict enforcement of testing (H. Wang et al., 2023). This is important because the government is a third-party oversight body. These high standards make it easier to check the quality of herbs and encourage companies and farmers to share information, which helps them all meet testing and certification requirements (Joo et al., 2018). The government is a key provider of public resources (Hong, 2018), so it is very important for it to assist with companies and farmers share information. In infrastructure development,

information platforms may aid in make sure that medicinal herbs are of good quality. Government support for creating public traceability platforms makes it easier to share information accurately, which makes it possible to control quality at every stage of making medicinal herbs (Haji et al., 2021). This study puts forth the following hypotheses based on the preceding analysis:

H7: Government support positively moderates the impact of supply chain information coordination on the quality of TCMM.

3.3.4 Moderating effect of government support on decision-making coordination for improving tcmm quality

Similarly, government support can also help facilitate decision-making coordination between companies and farmers, thereby improving the quality of TCMM. Support provided by the government, such as technology promotion, testing and traceability, public facilities, insurance and credit, standardized contracts, and law enforcement, can reduce the marginal cost for farmers and companies in their efforts to improve the quality of medicinal materials. Especially for farmers, government support provides financial, technical, and legal guarantees, promoting the enhancement of farmers' bargaining power in the supply chain (Ton et al., 2014).

For instance, government support can promote the effective participation of young farmers in activities to mitigate climate change (Ullah et al., 2024). With government support, farmers are more proactive in participating in supply chain decision-making coordination and improving the TCMM quality (J. Shi et al., 2022). Specifically, government support can provide third-party supervision and incentives for coordination between companies and farmers (Saenger et al., 2014), reduce the default risk (Klomp, 2013), and make the incentives brought by decision-making coordination more likely to be fulfilled, and the standards more enforceable, thereby amplifying the marginal effect of decision-making coordination on improving the TCMM quality. Based on the above analysis, this study proposes the following hypothesis:

H8: Government support positively moderates the impact of supply chain decision-making coordination on the quality of TCMM.

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Chapter 4: Research Design

This chapter mainly elaborates on the research design. Specifically, it includes five core sections. The questionnaire design section details the purpose and main content of the questionnaire, with a focus on the measurement items for each latent variable in the theoretical framework. The sample selection section explains the process of scientifically and reasonably selecting the research respondents, ensuring that the survey sample can reflect the overall perspectives of TCMM farmers and related companies as much as possible. The section of questionnaire survey forms introduces the survey methods adopted in accordance with the research subject and the characteristics of the respondents. The objective of this method selection is to design questionnaire items as comprehensive as possible to capture the respondents' views, thereby ensuring the reliability of the research conclusions. The questionnaire collection section illustrates the challenges during the collection process and the overall collection status. Finally, the research tools and methods section introduce the research methods and software tools used in this study.

4.1 Questionnaire design

4.1.1 Purpose of questionnaire design

In the preliminary research interviews of this study, several directors of TCM hospitals in Sichuan Province pointed out that TCM treatment is currently facing the problem of decreased efficacy of herbal prescriptions. The reduction in the efficacy of herbal prescriptions is not only due to individual differences among patients, but also, at a deeper level, to the decline in the quality of medicinal materials or their supply shortages. Chinese TCM hospitals must purchase all medicinal materials from large, nationally certified TCM companies to ensure medication safety. However, farmers often overuse pesticides or plant hormones during cultivation, leading to problems of excessive residue. These issues make it difficult for the medicinal materials to meet the standards required by enterprises. This has led to disruptions in the supply chain of some TCMM, making certain specific herbs unavailable in TCM hospitals. As a result, doctors have had to replace the missing herbs in prescriptions with alternatives that have similar effects. The shortage of key herbs ultimately reduces the effectiveness of the treatment.

Furthermore, if farmers do not use standardized methods of growing plants or suppliers do

not process them correctly, hospitals may end up with low-quality herbs. TCM prescriptions depend on the combined effects of several herbs. Thus, even adding one bad herb to a TCM prescription can make it much less effective overall. Addressing the quality of TCMM is a topic of concern.

Therefore, the goal of this study is to show how the "company + farmer" model for growing TCMM improves the quality of the herbs. Prior investigations into the determinants of medicinal herb quality have predominantly concentrated on scientific cultivation techniques, including seed selection, breeding, and field management practices (H. Liu et al., 2021; Lv et al., 2024; Müller et al., 2019). However, previous studies have paid less attention to how business models influence farmers' adoption of eco-friendly cultivation practices to enhance the quality of raw materials for TCMM. To investigate the specific mechanisms by which farmers enhance the quality of their TCMM within the "company + farmer" business model, this study necessitates data on: - The methods and degree to which medicinal herb cultivation techniques are transmitted from companies to farmers; - The coordination between companies and farmers within this framework; - The quality of medicinal herbs produced by farmers; - The influence of government support in promoting farmers' cultivation techniques and supply chain coordination within the "company + farmer" model.

However, because contract farming involves many small farmers and companies that are not listed, we can not get the information we need from public sources to test the research hypotheses in this work. Moreover, performing individual studies by means of interviews and experiments is prohibitively expensive, necessitating considerable human and material resources along with a significant temporal commitment. Relatively speaking, questionnaires offer the advantages of speed and broad coverage, enabling the collection of firsthand information within limited research budgets and timeframes. Specifically, they can gather vast amounts of data from a large number of farmers and TCMM enterprises in the shortest possible time, achieving highly efficient data collection.

Primary focusing on the development of the survey instrument, this chapter outlines the research design employed. With a Guided by the research framework established in Chapter 3, the questionnaire was designed to investigate the mechanisms through which the "company + farmer" model enhances the quality of TCMM, focusing on technology diffusion and supply chain coordination as primary drivers and the moderating role of government support. To this end, the survey specifically sought to assess the dynamics of technology sharing and adoption, examine the nature of information and knowledge coordination between the parties, and evaluate the government's role as a third-party supervisory force.

4.1.2 Development of the survey questionnaire

4.1.2.1 Overall approach to the survey questionnaire

Before conducting formal questionnaire surveys, this study conducted in-depth interviews on some existing issues affecting the quality of TCMM in current cultivation, in order to gain a clearer understanding of the problems in the supply chains of TCMM companies and farmers. Based on this foundational work, our research proposes targeted solutions to address these quality problems, thereby aiming to enhance the motivation of the companies and farmers involved.

This is primarily the way the questionnaire was designed. Based on interviews, we used established scales to create ways to measure variables that affect the quality of herbal medicine in the "company + farmer" cultivation model. After that, we chose the right questions and wording for the questionnaire to get the data we needed, which confirmed the model we built and the hypotheses we made. This study created a survey questionnaire that could be used by both companies and farmers. It focused on three areas of the "company + farmer" model: government support, agricultural technology diffusion, and supply chain coordination mechanisms.

This study adopted the widely accepted 5-point Likert scale developed by American social psychologist Rensis Likert to measure variables (R. Yang & Yagi, 2024). This scale consists of a series of questions or statements related to a specific topic. By aggregating the points assigned to each item in the scale, researchers can assess respondents' attitudes toward the survey topic or questions. In the scale, the point from 1 to 5 respectively represent "strongly disagree," "disagree," "neutral," "agree," and "strongly agree." Considering that nearly half of the respondents are peasant households, the questionnaire is designed with particular emphasis on conciseness, clarity, and practical operability.

Meanwhile, the number of questionnaire items is controlled within 35, with core and key questions retained. The completion time is controlled at approximately 6-8 minutes to minimize respondents' unwillingness in completing the questionnaire. Given the objective obstacles caused by different educational backgrounds and comprehension abilities of respondents, the questionnaire is designed in a concise presentation format with clear language. In addition, responses are collected anonymously to reduce the likelihood of dishonest responses due to sensitive information, thereby ensuring the questionnaire completion rate.

There are two main parts to the questionnaire for this study. The first section gathers demographic and operational data. For farmers, this includes personal information like their

gender, age, and level of education, as well as the specific kinds of TCMM they grow. The data gathered on companies included how long they had been in business, how they were owned, how many employees they had, how much money they made, and how many farmers they had on contract. The second part of the instrument measures the main variables of the study: how well people share and adopt technology, how well they coordinate information and decision-making, how much support the government gives, and how good the medicinal herbs are.

4.1.2.2 Variable measurement

To accurately gauge the variables in this study, the text methodically evaluated and curated items from well-established scales that are widely acknowledged and commonly employed by scholars, informed by comprehensive analysis of prestigious journals. This process first found 35 items, which made up the first questionnaire. This study created an initial questionnaire focusing on three areas: coordination mechanisms in TCMM business models, the diffusion of agricultural technology, and government support. A pilot survey was executed with randomly chosen executives from pharmaceutical companies, farmers at TCMM cultivation bases, and managers of TCMM manufacturing firms in Chengdu, Sichuan Province. Through ongoing communication, some of the survey's more complicated questions were made easier to answer, which made the questionnaire more useful for everyone.

With this as a starting point, we asked mentors to help us. We improved and changed the questionnaire items with the help of mentors and experts. This included deleting and changing content and modifying the order of the items. This process led to the completion of the official questionnaire, which was then sent out for testing. Next, this research will go into more detail about the specific content that needs to be designed for items:

(1) Measurement items for agricultural technology adoption (*TA*)

Drawing upon the seminal study of Davis (1989) on factors influencing users' acceptance of information technology, this study measures the construct of technology adoption from the perspectives of perceived usability and perceived ease of use. This research has been extensively cited by subsequent scholars. Statistics indicate that as a classic work on technology adoption, the study of Davis (1989) has been cited a staggering 89,049 times.

Due to differences in expression between Chinese and English, we translated the classic scales for perceived ease of use and perceived usability used by Davis (1989) into Chinese and made corresponding modifications based on the specific content of the items. The work, after taking into account the Chinese language setting and the particular theme of this study, ultimately delineated four specific items: *TA1*: The Chinese medicinal material cultivation

technology promoted by the company enables farmers to perform farming operations with less labor intensity. *TA2*: The Chinese medicinal material cultivation technology promoted by the company enables farmers to achieve higher planting efficiency. *TA3*: The Chinese medicinal material cultivation technology promoted by the company enables farmers to improve the quality of their medicinal material products. *TA4*: The Chinese medicinal material cultivation technology promoted by the company is relatively easy for farmers to master.

(2) Measurement items for agricultural technology sharing (*TS*)

Agricultural technology sharing represents a specific application of technology sharing within the agricultural sector. Therefore, this study adopts items from classic scales previously used in research to measure knowledge sharing to measure the construct of agricultural technology sharing. Based on the theory of reasoned action, Bock et al. (2005) explored factors influencing individuals' intentions to share knowledge from the perspectives of external motivation, social psychology, and organizational climate. Their study, considered a classic in knowledge sharing, had been cited 7,177 times as of September 2025.

Drawing on their research, this research identifies six related items from five perspectives: expected reciprocal relationships, sense of self-worth, connectedness, attitude toward technology sharing, and willingness to share technology. This scale can measure the comprehensive factors influencing individual knowledge sharing from a broader perspective. The specific measurement items for agricultural technology sharing are as follows: *TS1*: The company's sharing of TCMM cultivation technology has strengthened its connection with farmers. *TS2*: The company's sharing of Chinese medicinal material cultivation technology has increased the likelihood of future coordination with high-quality farmers. *TS3*: The company's sharing of cultivation technology has helped farmers solve problems. *TS4*: The company maintains close ties with farmers. *TS5*: The sharing of technology between the company and farmers is highly valuable to both parties. *TS6*: The company intends to share work experience or professional knowledge with farmers more frequently in the future.

(3) Measurement items for supply chain information coordination (*IC*)

The "company + farmer" model indicates that the quality of TCMM is a supply chain problem that affects both companies and farmers. Quality control at every stage, from growing to buying and processing, operates together. It's important to know how well companies and farmers work together to share information so that the quality of TCMM stays the same throughout the supply chain.

Supply chain integration is the way the primary company and its partners work together strategically and how well they work together across organisational lines. Strong relationships

between supply chain partners can make products better (Shin & Zeevi, 2024). Companies and smallholder farmers have very different information about contract farming. Smallholders typically lack access to comprehensive and equitable information from companies (Ruml & Qaim, 2021). Thus, reducing the information gap between businesses and farmers is essential for building trust between smallholders and businesses and helping farmers better understand the market.

Flynn et al. (2010) investigated the impacts of internal and external supply chain integration, along with their interactions, on organizational operations and business performance. They developed a supply chain integration scale measuring supplier integration, customer integration, and internal integration. Drawing on prior research (Flynn et al., 2010; Lawson et al., 2009), this work primarily focuses on information coordination between companies and farmers. Considering the characteristics of the "company + farmer" model for TCMM, we primarily identified information coordination between companies and farmers across six dimensions: variety information, cultivation plans, market demand forecasts for TCMM, current or historical market prices, company inventory levels, and medicinal herb testing results. The items in question are as follows: *IC1*: The company regularly shares information on high-quality medicinal material varieties with farmers. *IC2*: Farmers regularly share their planting plans with the company. *IC3*: The company regularly shares market demand forecasts for medicinal materials with farmers. *IC4*: The company regularly shares current and historical market prices of medicinal materials with farmers. *IC5*: The company regularly shares its medicinal material inventory information with farmers. *IC6*: The company regularly shares test results of the cultivated medicinal materials with farmers.

(4) Measurement items for supply chain decision-making coordination (*DMC*)

Coordination in supply chain decision-making is very important for making sure that everyone in the supply chain works together and that resources are used effectively. Prior studies demonstrate that effective collaborative decision-making among supply chain partners elevates the probability of future coordination, promotes the formation of enduring partnerships (Ramanathan & Gunasekaran, 2014), and improves the sustainability of delivered products (Allaoui et al., 2019).

The "company + farmer" model, especially for farmers, makes them feel fairer about making decisions about planting orders and harvesting, which makes them more willing to carry out those decisions. This increased batch trust, greater fairness perception, and higher willingness to execute that come from companies and farmers working together to make decisions all improve the quality of TCMM and the performance of the company (Ramanathan

& Gunasekaran, 2014).

Soosay et al. (2008) pointed out that decision-making coordination in the supply chain can establish procedures when dealing with partners, engage in joint planning and investment, and ultimately improve operations, systems, and processes within the supply chain. Their research provides insights into how to establish collaborative relationship strategies. Referring to previous studies (M. Cao & Zhang, 2011; Soosay et al., 2008), and considering the characteristics of power balance between companies and farmers in the "company + farmer" medicinal herb planting model, this study identifies specific items from the perspective of drafting order-related terms. Specifically, this study determined five items from the perspectives of medicinal herb acceptance quality standards, order prices, delivery times, and settlement methods. These are: *DMC1*: The company considers the opinions of farmers when establishing quality standards for medicinal materials. *DMC2*: The company considers the opinions of farmers when setting order prices for medicinal materials. *DMC3*: The company considers the opinions of farmers when determining order quantities for medicinal materials. *DMC4*: The company considers the opinions of farmers when setting delivery schedules for medicinal materials. *DMC5*: The company considers the opinions of farmers when establishing payment terms for medicinal materials.

(5) Government-supported measurement items (*GS*)

Government support is very important for agricultural development. This usually comes in the form of financial aid or advice for farmers (Alizamir et al., 2019; Mastenbroek et al., 2021). The Chinese government has given a lot of policy and financial support to the TCMM industry. This is especially true for the cultivation of TCMM. This part makes a variable for government support to see how it affects the quality of TCMM by making it easier for technology to spread and for the "company + farmer" model to work collaboratively.

The Chinese government plays a pivotal role in the country's economic and social development. This characteristic distinguishes China from other nations. Therefore, this study primarily adopts established scales developed by Chinese scholars to measure government support. Specifically, drawing upon prior research (H. Li & Atuahene-Gima, 2001; Y. P. Yang et al., 2019), this research identifies four items across four dimensions: policy awareness, financial subsidies, technical support, and government oversight. The items are as follows: *GS1*: You are well-versed in the government-provided subsidy policies for cultivation techniques. *GS2*: Government support covers the primary costs of investing in new technologies. *GS3*: Agricultural technicians' on-site guidance has addressed the challenges in technical application. *GS4*: Government regulation has prompted the adoption of more quality-oriented technologies

and management practices in medicinal material production.

(6) Quality measurement items for chinese herbal medicines (*QE*)

The quality of TCMM is the main thing this study is aimed at. There is no standardized measurement scale for evaluating the quality of herbal medicine; however, a thorough assessment methodology has developed over centuries of cultivation. This method combines looking at the appearance, taste, and size of the herbal medicine with tests of its physical and chemical properties to figure out how good it is.

Therefore, this study primarily establishes relevant assessment items for measuring the quality of TCMM based on the corresponding provisions in the 2025 edition of the Pharmacopoeia of the People's Republic of China. Specifically, this study focuses on setting specific assessment items concerning active ingredient content, pesticide residue testing, heavy metal content testing, and the appearance characteristics of the herbal materials. The following are the quality measurement items for TCMM: *QE1*: The active ingredient content of the produced medicinal materials complies with the relevant standards of the Chinese Pharmacopoeia. *QE2*: The pesticide residue test results for medicinal materials produced in the past three years have all complied with national and industry standards. *QE3*: The heavy metal test results for medicinal materials produced in the past three years have all complied with the standards. *QE4*: The produced medicinal materials exhibit satisfactory organoleptic characteristics (e.g., color, odor, shape, texture).

(7) Basic information variable statistics

Based on the entities involved in the "company + farmer" model, this study distributed questionnaires to both companies and farmers. The fundamental inquiries concerning primary variables remained uniform across questionnaires, albeit with minor modifications to cater to distinct respondent groups. As a result, there are differences in the statistical analysis of basic demographic variables. This study aimed to comprehend the socio-demographic characteristics of farmers, encompassing age, gender, educational attainment, and other relevant factors. The research also necessitated the collection of data regarding their cultivation practices, including the specific areas and varieties of medicinal materials cultivated. At the company level, the focus was on gathering information regarding scale and profitability. Detailed questionnaire content is provided in Annexes. By integrating items from all these sections, the preliminary survey questionnaire for this research was ultimately developed.

4.1.2.3 Assessment and pre-testing

Prior to the large-scale distribution of the formal questionnaire, to ensure the quality of the questionnaire and the feasibility of the research, minimize measurement errors to the greatest extent possible, and guarantee the validity and reliability of the final collected data, this study invited relevant experts to evaluate the questionnaire and conducted a pre-test.

(1) Assessment

Content validity refers to the extent to which the items or questions included in a measurement tool represent or cover the specific content domain or construct intended to be measured. Specifically, for this study, content validity concerns whether the questionnaire items comprehensively and accurately measure technology diffusion (technology adoption, technology sharing), supply chain coordination (information coordination and decision-making coordination), government support, and TCMM quality. Since content validity assessment relies primarily on logical analysis and expert judgment rather than statistical calculations, this study invited experts in TCMM quality supervision and professors of management to evaluate the content validity of the survey questionnaire.

To guarantee the reliability and validity of the measurement instruments, all scales employed in this study's questionnaire are derived from classic or well-established scales within their respective domains. We made the necessary changes based on this foundation to fit the needs of this research. After we made the first draft of the questionnaire, we asked professors from Chengdu University of Traditional Chinese Medicine, researchers from the Sichuan Provincial Institute for Drug Control, my advisor, and other management professors to give us ideas for changing the questions. Based on their comments, we took out two items from the technology adoption section because they were too similar to other items and the wording was not clear. We also made changes to four questions about technology sharing and the quality of TCMM based on expert advice in order to improve the theoretical logic, clarity of expression, and presentation format of the questionnaire design.

It should be noted that the specific variable measurement items shown in Section 4.1.2.2 above are the revised versions that were made with the help of experts. With the help of experts, we improved the measurement variables as a whole, making them much completer and more relevant while avoiding oversimplification and irrelevant interference. This process made the study's measurement tools more reliable and acceptable, which set the stage for the next round of preliminary reliability and validity tests.

(2) Pre-test area

This study chose Sichuan Province, which has a lot of natural resources, as the place to run the first test. Sichuan has an abundance of TCMM. China's medicinal plant resources can vary in different parts of the country. In terms of the geographical distribution of authentic TCMM, China's herbal resources are primarily concentrated across six natural regions. Among these, the Chengdu-Chongqing region—represented by Sichuan, Chongqing, Yunnan, and Guizhou—accounts for 24.85% of authentic medicinal herbs, ranking first among the six natural regions (G. H. Zhang et al., 2023). This provides a natural environment conducive to farmers cultivating TCMM.

Sichuan Province is in the subtropical part of southwest China. The different types of soil and weather there are great for growing TCMM herbs. Sichuan has the most authentic medicinal herb varieties in the country, making up about a quarter of the national total. This is because people have been growing them there for hundreds of years. The Fourth National Survey of Traditional Chinese Medicine Resources reports that Sichuan has 86 real medicinal herb species and a total of 7,290 TCMM resources (J. N. Zhao et al., 2020). Panzhihua City in Sichuan has even turned its medicinal plants into a tourist attraction. This means that using Sichuan as the test site can fully test whether the questionnaire items that cover different medicinal plant traits are useful in all situations.

Sichuan Province has a wide range of cultivation scales for TCMM. There are many different ways of doing business in the province. These include traditional small-scale peasant farming, "company + farmer" cooperative models, and large-scale businesses that run standardized, large-scale GMP-compliant production bases for medicinal herbs. These organizations, which range in size, have different ways of managing quality, different technical skills, and different areas of focus. This is the perfect "stress-testing" setting for testing how easy it is to understand and apply questionnaire items to people from different backgrounds.

Sichuan Province is a top place for scientific research and policy-making. Chengdu University of Traditional Chinese Medicine and other high-quality TCM schools are located in the province, along with many national and provincial research institutes. The existence of these institutions indirectly indicates that local practitioners may exhibit superior cognitive abilities and a heightened focus on the notion of "quality." Administering questionnaire surveys to these subjects can elicit more profound and constructive feedback.

Hence, doing pre-tests in Sichuan can help find as many problems as possible with the questionnaire's content validity, surface validity, linguistic clarity, logical structure, and applicability. This offers the most substantial and dependable empirical foundation for

subsequent amendments prior to nationwide formal execution, thereby effectively guaranteeing the scientific integrity and validity of the final research.

In initial stage, this study randomly selected TCMM companies and peasant households from several TCMM planting bases in Sichuan Province for a pre-survey. A total of 50 questionnaires were distributed and 48 were returned. After excluding 2 invalid responses, the effective response rate was 92%.

(3) Pre-test reliability analysis

The pre-test data involves six dimensions: technology adoption, technology sharing, supply chain information coordination, supply chain decision-making coordination, government support, and the TCMM quality. Referring to previous research (Cronbach, 1951), the reliability of the collected data was assessed using Cronbach's α coefficient. A Cronbach's α coefficient value above 0.8 indicates high reliability; a value between 0.7 and 0.8 indicates good reliability; a value between 0.6 and 0.7 indicates acceptable reliability; and a value below 0.6 indicates poor reliability.

In addition, this study also reports the Dijkstra-Henseler reliability coefficient and composite reliability of the pretest data. The Rho_A value in SmartPLS, proposed by Dijkstra and Henseler (2015), is a reliability coefficient based on the consistent PLS algorithm. This method considers measurement errors and the correlations between constructs, providing a more accurate reflection of the internal consistency of the constructs. A Rho_A value of ≥ 0.70 indicates good construct reliability. Composite reliability reflects the consistency among all items within a construct. A Rho_C value of ≥ 0.70 signifies good construct reliability. Table 4.1 report the reliability test results for each variable in the pretest data.

Table 4.1 Reliability test results for variables in the pilot test data

Construct	Number of items	Cronbach's α	Rho_A	Rho_C
Technology adoption	4	0.897	0.908	0.929
Technology sharing	6	0.933	0.934	0.947
Information coordination	6	0.927	0.929	0.942
Decision-making coordination	5	0.930	0.931	0.947
Government support	4	0.872	0.874	0.912
Quality of TCM	4	0.911	0.911	0.938

As shown in Table 4.1, the Cronbach's α coefficient for the six dimensions—technology adoption, technology sharing, information coordination, decision-making coordination, government support, and TCMM quality—has a minimum value of 0.872, exceeding the critical threshold of 0.70 required in most social science research (Nunnally & Bernstein, 1994). Furthermore, the minimum values for both Rho_A and Rho_C exceed the 0.70 threshold, indicating that the constructs in this study possess good reliability. Therefore, the above analysis

demonstrates that the scales designed in this study meet the basic requirements for acceptable internal consistency reliability and exhibit good reliability.

(4) Pre-test Validity Analysis

In SmartPLS, the Fornell-Larcker criterion serves as the core method for assessing discriminant validity. Its fundamental logic is that the square root of a construct's average extracted variance (AVE) should exceed the correlation coefficient between that construct and other constructs (Fornell & Larcker, 1981). This criterion checks to see if a construct is different from others by comparing the shared variance between the construct and its own indicators (the square root of AVE) to the shared variance between constructs (correlation coefficients). The Fornell-Larcker criterion analysis results are shown in Table 4.2.

Table 4.2 Fornell-larcker criterion analysis

	DMC	GS	IC	QE	TA	TS
DMC	0.884					
GS	0.770	0.850				
IC	0.806	0.708	0.856			
QE	0.725	0.794	0.697	0.889		
TA	0.575	0.578	0.616	0.616	0.875	
TS	0.701	0.657	0.744	0.714	0.795	0.865

In the construct-related correlation matrix, the square root of the AVE for each construct surpassed its correlation coefficients with other constructs. This finding confirms the validity of the pretested questionnaire utilized in this study.

4.2 Selection of questionnaire survey samples

China's huge land area covers a wide range of climates, from tropical to subtropical to temperate. This means that temperatures can vary a lot. The country has a lot of different types of land, including mountains, coastal tidal flats, plains, hills, plateaus, and basins. There are many different types of soil, as well. For example, loess, black soil, and acidic red soil can all be found in different places. This geographical diversity has resulted in the extensive regional proliferation of TCMM cultivation across the country.

This study chose 21 provinces as the survey areas to get the most diverse and representative data from the questionnaire. To keep the sample representative and the data rich, a multistage stratified sampling strategy was used.

The current investigation utilizes stratified sampling for regional selection, categorizing based on levels of economic development. The study used Chengdu City as an example of an economically developed area in Sichuan Province. Conversely, Nanchong City (which includes

Nanbu County, Yilong County, and Peng'an County), Bazhong City, and Liangshan Yi Autonomous Prefecture are served as less developed areas. This spatial layout is designed to cover planting entities in different macro-environments. Based on this principle, we distributed questionnaires across various economic regions nationwide.

This study strives for balance within each survey site and uses quota sampling based on key variables. Educational attainment may affect how well farmers understand and accept new farming technologies and ideas about quality management. At the same time, the size of the farm affects how much risk farmers are willing to take, how they invest, and how much power they have in the market. These differences can cause farmers to have very different views and make quite various decisions when growing TCMM. Thus, when we chose farmer samples, we took into account all the differences between farmers, like their level of education and the size of their farms.

Finally, this study employed stratification among TCMM manufacturers in the selection of the corporate sample. To get a wide range of information and insights from different parts of the industrial chain, employees from different functional areas, like production, quality control, procurement, and management, were surveyed.

4.3 Formats of questionnaire surveys

To effectively gather a substantial amount of data for this study, we implemented a combination of online and offline questionnaire surveys.

This study applied anonymous questionnaires to survey farmers engaged in the cultivation of TCMM. This method makes farmers feel more comfortable answering questions that are private, sensitive, or socially unacceptable, which could lead to more honest answers. It does not put pressure on the interviewee or make them feel like they have to accommodate the interviewer, which can happen in person. The survey questionnaire was sent out through a number of different channels, with SoJump being the main one. SoJump is a popular survey software platform in China. In addition, to get the most people to fill out the questionnaires and get more useful data, different ways to fill them out were offered during data collection based on the research goals and target demographics.

The research used the SoJump platform to make an electronic survey to make it easier for people to fill out the questionnaire. Individuals who answered the questionnaire could do so on their mobile phones by scanning a QR code. Furthermore, the platform sent out the questionnaire through electronic links, which worked for people who use computers. Some

older farmers may not be familiar with computers or smartphones; therefore, paper questionnaires were also given out at cultivation bases in Sichuan Province so that people could fill them out by hand.

4.4 Questionnaire collection

4.4.1 Questionnaire collection process

For this study, gathering questionnaires is a big problem. On one hand, China's large size and the fact that TCMM cultivation bases are distributed out across the country, sometimes with large geographical gaps between them, make it hard to get responses. On the other hand, there are not many companies or herbal medicine farmers compared to the general population of businesses and farmers, which makes it even harder to find individuals who can take the survey.

However, choosing Sichuan Province as the main area for this study's survey alleviates worries about how well the questionnaire represents the whole population. Sichuan Province is the top producer of authentic TCMM (J. N. Zhao et al., 2020). Consequently, we focused our research on Sichuan-based companies that grow TCMM and farming families. We used a door-to-door survey method to get the most responses to the questionnaire. This method greatly improved both the number and quality of our sample.

In this study, a total of 640 questionnaires were distributed both online and offline. Finally, 582 responses were collected through WeChat, email, postal mail, and on-site surveys. Among these, 265 were completed by companies and 317 by peasant households, with an overall response rate of 90.94%.

Statistical analysis of the returned questionnaires shows that the provinces with the highest number of returned questionnaires are Sichuan, Guizhou, Jiangsu, and Anhui. These provinces are representative of major TCMM production regions. Therefore, in terms of the source distribution of questionnaire responses, the process of questionnaire distribution and collection in this study is reasonable.

4.4.2 Handling of careless responses

This study adopted a combined online and offline questionnaire collection method. Notably, however, most questionnaires were collected through online channels. Online questionnaire collection inevitably faces the problem of careless responses caused by respondents' lack of attention and motivation, which may lead to collected data failing to accurately reflect the true

situation (J. L. Huang et al., 2015).

Ward and Meade (2023) systematically explored methods for preventing, detecting, reporting, and cleaning careless responses in survey data, and provided recommendations for screening protocols of varying strictness. Based on their research, this study accordingly addressed potential careless responses in the 582 collected questionnaires. The specific steps are as follows:

4.4.2.1 Response time

A common way to find careless answers is to use rapid response. In some cases, a survey response speed that is too fast may mean that the person who answered did not take it seriously. Because very short response times make it almost impossible for people to read, understand, and answer survey questions correctly, a minimum time limit can be set to weed out people who did not take the survey seriously (Ward & Meade, 2023).

The response time method is easy to understand and can help find responses that are too quick, but it does not work in all situations. For instance, if people are doing more than one thing at once or get distracted in the middle of the process, like when they stop or interrupt their survey participation, the total response time may not be able to pick up on careless answering behaviors that happen quickly and randomly. Monitoring page-wise response time, on the other hand, can pick up on big changes between different pages and is usually more sensitive than total duration-based detection.

The survey platform SoJump utilized in this study does not furnish response times for individual items, but rather the aggregate completion time for each questionnaire. Based on previous research (Bowling et al., 2016), this study determined the average response time per item by dividing the total response time of each questionnaire by the number of items. Finally, eight questionnaires were taken out because the average time it took to answer them was less than two seconds.

4.4.2.2 Invariance

Invariance, also referred to as “straight-lining” or “patterned” responding (Johnson, 2005), is a type of careless response characterized by respondents providing identical consecutive answers to a series of survey items or following a mechanical repetitive pattern. For example, respondents may response with recurring A, B, A, B throughout the questionnaire. As such, this type is often regarded as one of the fastest response ways.

To address unreliable questionnaire data caused by invariance and similar careless

responses, questionnaires with consecutive identical responses or repetitive response patterns were excluded in this study. Specifically, following previous research (Marjanovic et al., 2015) in dealing with careless responses, inter-item standard deviation was used to identify random responders and eliminate meaningless or invalid responses in this study. Marjanovic et al. (2015) pointed out in their study that a larger inter-item standard deviation implies a higher likelihood of random responders, while a smaller value corresponds more conscientious responders. According to their study, inter-item standard deviation method can correctly identify responders with a classification accuracy rate of up to 80%. Using the inter-item standard deviation proposed by Marjanovic et al. (2015), this study removed 16 questionnaires with inter-item standard deviation exceeding 80%.

4.4.2.3 Consistency

Consistency refers to the degree to which data presentation aligns with theoretically or logically expected patterns or those based on existing data trends. From a psychometric perspective, two items that demonstrate high homogeneity in content or concept are logically expected to yield convergent responses from respondents. But the contrary is not the case. By reference to suggestions from Ward and Meade (2023), this study eliminates inconsistent questionnaires by calculating the inconsistency indicators. To alleviate this problem, we have removed a total of 13 questionnaires which failed to achieve the desired consistency level.

4.4.2.4 Outlier

The Mahalanobis distance can assess the extent to which an individual respondent deviates from the overall pattern in a sample and is a method for detecting multivariate outliers. The advantage of this metric is that it can be relatively easily obtained in most statistical software and can be widely applied to different types of datasets. Moreover, unlike traditional methods that use only a subset of items, the Mahalanobis distance utilizes information from all survey items, allowing for more thorough detection of unusual patterns in the data. Referring to the study by Ward and Meade (2023), we calculated the Mahalanobis distance and removed six outlier responses from the questionnaire.

Overall, referring to previous research (Ward & Meade, 2023), we used four methods—response time, invariance, consistency, and outliers—to cumulatively address 43 careless responses (7.39%) in the returned questionnaires caused by various reasons. In the end, we had 539 valid questionnaires, with an effective questionnaire rate of 92.61% (539/582). Considering the overall valid questionnaire rate, the overall effective rate in this study was 84.22% (539/640).

4.5 Research tools and methods

4.5.1 Descriptive analysis

Descriptive analysis is a statistical technique for compiling data and conducting basic analysis. Descriptive statistics primarily concentrate on the central tendency of data (including mean, median, and mode), the extent of dispersion (such as standard deviation and range), and the configuration of the data distribution (for instance, normal distribution and skewed distribution). This method shows the basic features of data in a way that is easy to understand, without looking at the complicated causal links that are behind the data.

The first step in analysing the data was to use descriptive statistics to sum up the main features of the sample. For example, we found the mean and standard deviation for important ideas, like how willing respondents were to share technology. This first step is very important for putting survey data in order and making it shorter, which makes it possible to find central tendencies and distributions. The descriptive analysis lays the groundwork for the next inferential statistical tests by giving a clear picture of the situation.

4.5.2 Reliability analysis method

Reliability analysis is an important way to check how good assessment questionnaires are. It gauges the extent to which the same test can be relied upon to produce uniform results, primarily indicated by the consistency, reproducibility, and stability of test outcomes. This method is used a lot in many areas, such as psychology, education, and the social sciences.

There are two types of reliability: internal and external. External reliability is how consistent the results of a survey are when measured at different times. Internal reliability shows if a group of survey questions measures the same idea. When estimating reliability coefficients using a single measurement, internal reliability is employed for testing. Cronbach's alpha is the most widely used measure of internal reliability.

According to the data type of the Likert multi-choice scale, we employed the α reliability coefficient. This coefficient is capable of measuring the consistency between scores of each item in the scale, and therefore it is applicable for questionnaire data subject to multiple scoring. Moreover, in this study, both the Dijkstra-Henseler reliability coefficient and the composite reliability (Rho_C) are employed to verify the reliability of a questionnaire.

During questionnaire analysis, SmartPLS is used for survey data verification and processing. This enables the internal reliability value of a questionnaire to meet the analysis

requirements. The higher the Cronbach's α coefficient, the better the reliability of a questionnaire is. When the α value is lower than 0.600, it indicates a lower reliability, and it is necessary to re-design the questionnaire until the requirements for reliability analysis are met. When the α value ranges between 0.600 and 0.700, it indicates that, though acceptable, it is not convincing. Therefore, proper adjustment must be made to the current scale. When the α value ranges between 0.700 and 0.800, it indicates the measurement results are acceptable and are highly reliable. When the α value is greater than 0.800, it indicates sound consistency and high stability of the questionnaire.

Rho_C reported by SmartPLS is an improved version of the traditional composite reliability (CR). It is calculated on the basis of the PLS algorithm and reflects the degree of consistency of all items under a construct. Rho_C ≥ 0.700 indicates good reliability of the construct; 0.600 < Rho_C <0.700 indicates acceptable reliability; Rho_C <0.600 indicates poor reliability.

Dijkstra-Henseler reliability coefficient (Rho_A) is a reliability coefficient on the basis of the consistent PLS algorithm. Rho_A ≥ 0.700 indicates good reliability of the construct; Rho_A <0.700 indicates poor reliability.

4.5.3 Validity analysis method

The validity analysis method is often used for evaluation of the validity of a measuring tool, especially the validity of questionnaire design. This statistical method investigates to see how accurately the measurement results can demonstrate the measured concepts or characteristics. As an important statistical method, it ensures the reliability and validity of research results.

During the questionnaire design phase, validity analysis of pretest data can help find issues like unclear question wording and illogical response options, which can then be fixed and improved. Additionally, in statistical analysis, validity testing is necessary to determine if the questionnaire or data can be analyzed further. This study utilizes SmartPLS statistical analysis software to assess the validity of both the pretest and formal questionnaire surveys. Based on previous studies, the main ways to check validity are cross-loadings and the Fornell-Larcker criteria.

Cross loadings method. A loading represents an item's contribution to its own latent variable. Cross loadings, conversely, indicate an item's contribution to other latent variables. An item's loading on its primary construct should exceed the sum of its loadings on all other constructs; otherwise, it indicates poor validity.

Fornell-Larcker criteria. Average variance extracted (AVE) itself serves as a measure of

convergent validity, but it also proves useful in assessing discriminant validity. It represents the extent to which a latent construct explains variance in its indicators. If a construct's AVE is greater than the square of its correlation coefficients with other constructs, it indicates good construct validity; the opposite suggests poor validity.

4.5.4 Structural equation models

Structural equation modeling (SEM) is a method for analyzing multiple variables at once. It combines several techniques, including factor analysis, multiple regression analysis, and path analysis, to create a complete analytical framework. SEM is a multivariate statistical method employed to examine intricate relationships among variables. Unlike regression analysis, which usually only looks at observable variables, SEM can process at both latent variables and the measurement error that goes along with them at the same time. Additionally, it can test complicated theoretical models all at once, which gives it a lot of flexibility (Kline, 2023). As a result, SEM is now a popular way to analyse data in fields like economics, psychology, and the social sciences.

The purpose of this work is to explore the possible mechanisms by which the "company + farmer" model can improve the quality of TCMM from the perspectives of technology diffusion and supply chain coordination. Combined with the research framework, we need to measure technology adoption, technology sharing, supply chain information coordination, supply chain decision-making coordination, government support, and the quality of TCMM. Most of the variables required in this study are latent variables, which are difficult to observe directly. Structural equation modeling can not only handle specific indicators or questionnaire items that can be directly measured, but also examine the relationships between latent variables and observed variables. Therefore, we chose structural equation modeling as the key statistical analysis tool.

Specifically, this study uses a structural equation model to analyze the factors affecting the quality of TCMM in the "company + farmer" planting model, such as technology diffusion, supply chain coordination, and government support. This is because the cultivation of TCMM involves certain latent variables related to social environment and individual psychological aspects of both the farmers and the companies that cannot be directly observed.

For example, in the case of farmers, whether they consciously choose organic methods to grow medicinal herbs, their learning and adoption of advanced cultivation techniques shared by the company, and their views on government-provided support. For the company, we want

to measure its willingness to share advanced techniques with farmers as well as information related to market prices and demand for medicinal herbs. These latent variables are difficult to measure accurately and directly. Traditional statistical methods are not suitable for handling such variables. However, structural equation modeling can appropriately handle both latent variables and indicators simultaneously, providing a reliable data analysis method for research purposes.

Using structural equation modeling to analyze a survey questionnaire involves three key steps. First, determine the specific model structure based on the research questions and theoretical hypotheses. The crucial point is that researchers need to clearly identify which are latent variables, which are observed variables, and the potential relationships between them. In other words, in the first stage, researchers propose the research framework based on previous studies and the practical problems that exist.

The second stage is to design, distribute, and collect the survey questionnaires to obtain the research data needed for the study. The data is then organized and preprocessed, which is known as data cleaning. After that, the right models and estimation methods are chosen based on the data's features to estimate the parameters of the built structural equation model. This shows how variables are related and how strong those relationships are. Structural equations mainly offer two categories of models: covariance-based structural equation models and variance-based partial least squares structural equation models.

Following this, the most important part of data analysis comes next. Prior to formal analysis, the model's validity and the data's suitability must be assessed utilizing various fit indices. Researchers need to change the model when it does not fit well. Changes could mean changing how variables relate to each other or adding or removing variables.

Finally, the research hypotheses are tested using the model's estimates of parameters and the results of testing the relationship between dependent variables at significance levels. Based on this, the results of the data analysis are used to answer the research questions and help people make decisions.

4.6 Chapter summary

To separately examine the relationships among agricultural technology diffusion, supply chain quality coordination, and the improvement of TCMM quality, and to test the moderating role of government support in these relationships, this chapter employs a questionnaire survey to quantify relevant indicators.

First, we used quantitative research to create relevant items that would help us measure latent variables within the research framework. This chapter explains where the measurement items for technology adoption, technology sharing, information coordination, decision-making coordination, government support, and the quality of TCMM come from, as well as what they are about. We also go into more detail about how we designed the questionnaire, which included asking experts to look at the draft and make suggestions for changes. We then did a pilot study in Sichuan Province, checked the validity and reliability of the results, and finished the official survey questionnaire.

Furthermore, this work elaborates in detail on the complete process of the questionnaire from official distribution to collection, specifically including the selection of survey samples, the form of the questionnaire survey, and the process and results of collecting the questionnaires. Unlike studies on topics such as shopping preferences or brand loyalty, which involve a large number of respondents, the cultivation of TCMM is a relatively smaller and more specific research issue, involving a smaller number of subjects. Therefore, in the questionnaire survey of this study, in order to improve the reliability and authenticity of the research data, we invested a considerable amount of time and effort in distributing and collecting the questionnaire data.

Additionally, this chapter further discusses about the research methods and rules that were used in the later sections of the empirical analysis. This provides data support and sets up a method for the empirical analyses in the next chapters.

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Chapter 5: Empirical Analysis

The goal of this chapter is to use statistical analysis on 539 valid questionnaires that were collected using the "company + farmer" model for growing TCMM. This will help us test the theoretical model and research hypotheses that were put forward in this study. We used the well-known SmartPLS 4.0 software to analyze our data through Partial Least Squares Structural Equation Modeling (PLS-SEM). This approach is especially appropriate for exploratory research, theoretical advancement, and the management of intricate models, which corresponds effectively with the aims of this study. The analytical process in this chapter mainly includes processing data and descriptive statistics, testing the measurement model's validity and reliability, and testing the structural model's hypothesis.

5.1 Analysis of descriptive statistics

There are two main parts to the descriptive statistical analysis in this section. To begin, we look at the sociodemographic traits of the formal sample to see how the respondents (including companies and farmers) are spread out across these traits. Second, we use specific indicators like valid sample size, mean, standard deviation, skewness, and kurtosis to do a descriptive statistical analysis on each measured variable. This descriptive analysis aids in comprehending respondents' general perception levels for each variable and evaluates the normality of the variables.

5.1.1 Analysis of socio-demographic characteristics

In gathering data, we took into account the sociodemographic traits of the two main groups in the "company + farmer" TCMM cultivation model—companies and farmers—in order to fully understand how this model affects the quality of medicinal herbs. Consequently, in the design of the questionnaire, we customized various fundamental information items for each entity to enhance our understanding of the characteristics of both the participating farmers and companies within this model.

5.1.1.1 Company's socio-demographic characteristics

Table 5.1 presents the key characteristics of the respondents at the company level in our survey sample on the quality improvement of TCMM. In terms of firm age, 38.72% of the respondent companies are newly established, being in operation for less than five years. Additionally, companies with more than 20 years of operation account for 23.31% of the sample. Regarding the ownership structure of the respondent companies, over 90% of the firms in our survey sample are either privately-owned or state-owned enterprises, accounting for 74.06% and 16.54% of the total, respectively.

Table 5.1 The basic demographic characteristics of the company-level respondents

Item	Category	Percentage
Firm Age	0-5 years	38.72%
	6-10 years	26.32%
	11-20 years	11.65%
	21 years and above	23.31%
Ownership Type	State-owned	16.54%
	Private	74.06%
	Foreign-funded	0.38%
	Collectively-owned	2.63%
	Other	6.39%
Total Assets	0-1 million CNY	34.59%
	2-10 million CNY	25.19%
	11-100 million CNY	20.68%
	101 million CNY and above	19.55%
Revenue	0-3 million CNY	45.86%
	4-20 million CNY	21.43%
	21-100 million CNY	15.79%
	101 million CNY and above	16.92%
Number of Employees	0-50 employees	56.77%
	51-100 employees	15.79%
	101-200 employees	7.14%
	201 employees and above	20.30%
Number of Farmers under Contract	0-50 farmers	42.48%
	51-100 farmers	29.70%
	101-200 farmers	9.02%
	201 farmers and above	18.80%
Position	Senior management	30.45%
	Department head	13.16%
	Middle management	15.79%
	Technical professional	12.78%
	Frontline operations staff	27.82%

In terms of company size, small and micro enterprises constitute a relatively large proportion of our survey sample. Specifically, companies with total assets of not exceeding 1 million CNY represent the largest group, accounting for 34.59%. However, overall, the distribution of companies across different asset sizes is relatively balanced. The data shows that there is an inverse relationship between revenue levels and the number of companies. As

revenue levels go up, the number of companies in each level goes down. In particular, 45.86% of the sample are companies with annual revenues of less than 3 million RMB, while 16.92% are companies with revenues of more than 100 million CNY. An analysis of workforce size indicates that 56.77% of the surveyed companies employ a workforce of no more than 50 employees. This distribution pattern shows that most of the companies in our survey sample are small, medium, or tiny companies when it comes to total assets, revenue, and number of employees.

The companies we investigated in our study are the ones that have made agricultural contracts with farming families. Therefore, we also looked at how many farmers they had signed agricultural contracts with in the past. Our results demonstrate that in our survey sample, 42.48% of companies work with fewer than 50 farming households and 29.70% work with 50 to 100 farm households. This data supports the main feature of our sample, which is that most of the businesses are small.

The top three job positions among our respondents were senior management personnel (30.45%), frontline operational staff (27.82%), and middle management personnel (15.79%). Overall, respondents from different job levels each made up at least 10% of the total. This shows that the survey data accurately reflects the views of people at different levels of the organization.

5.1.1.2 Farmer's socio-demographic characteristics

Table 5.2 shows the basic socio-demographic profile of the farmers in the survey sample. In terms of gender, 65.19% of the sample were males and 34.81% were females. This means that there were about twice as many males as females. Most of the people who answered were between the ages of 25 and 54. 7.28% of the individuals who responded were in the 18–24 age group, which was the youngest. Twenty percent of the people who participated had less than a high school education, and the largest group (28.80%) had an associate degree. Only 4.11% of the individuals who participated in the survey have master's degrees or higher. In general, the level of education among the individuals that we surveyed was not very high.

Table 5.2 The basic socio-demographic profile of the farmers

Item	Category	Percentage
Gender	Male	65.19%
	Female	34.81%
Age	18-24 years	7.28%
	25-34 years	24.05%
	35-44 years	27.22%
	45-54 years	28.16%
	55 years and above	13.29%
Education Level	Below high school	20.89%
	High school/Secondary specialist	18.99%

	Associate degree	28.80%
	Bachelor's degree	27.22%
	Master's degree and above	4.11%
Experience in Cultivating TCMM	0-5 years	64.24%
	6-10 years	26.27%
	11-20 years	6.65%
	21 years and above	2.85%
Scale of TCMM Cultivation	0-3 mu	41.14%
	4-10 mu	22.78%
	11-30 mu	9.18%
	31-100 mu	10.13%
	101 mu and above	16.77%
Topography for TCMM Cultivation	Mountains, Hills/Mountains, Plateau, Valleys	55.38%
	Plain, Basin, Alluvial Fan	37.66%
	Coastal Plain, Coastal Hills, Tidal Flats, Island	6.33%
	Desert, Gobi (Gravel Desert), Grassland, Loess Hills	0.63%
Membership in Agricultural Cooperative	Yes	41.46%
	No	58.54%
Available Household Labor Force	1 person	11.39%
	2 persons	40.51%
	3 persons	26.58%
	4 persons	11.08%
	5 persons and above	10.44%
Participation in Agricultural Insurance	Yes	60.44%
	No	39.56%
Access to Formal/Informal Credit	Yes	43.04%
	No	56.96%
Whether any household member holds a position as a village cadre or is employed in a government/public institution	Yes	39.24%
	No	60.76%

Note: 1 mu ≈ 0.1647 acres

Since our research focus is on the quality of TCMM cultivation, we not only gathered basic demographic data such as the farmers' gender, age, and education level, but we also created survey questions specifically about cultivation practices to get information about the respondents' main agricultural production.

A large number of people who completed the survey had less than 10 years of experience growing Chinese medicinal herbs. In particular, 64.24% of those who answered had 0–5 years of experience, 26.27% had 5–10 years, and only 9.50% had more than 10 years of experience. This cultivation experience suggests that most of the herbal farmers in our survey sample currently do not have enough knowledge. Therefore, examining the efficacy of the "company + farmer" herbal cultivation model in improving farmers' cultivation techniques is of practical importance.

Our sample's respondents showed an inverted U-shaped distribution when it came to the scale of TCMM cultivation. This is shown by the larger percentages of people who grow less

than 10 mu and more than 30 mu. In particular, 41.14% of the respondents were growing 0–3 mu, and 22.78% were growing 3–10 mu. For cultivation on a slightly larger scale, 10.13% of respondents were farming 31–100 mu, and 16.77% were farming more than 100 mu. But less than 10% of the farmers were medium-scale farmers who grew 11 to 30 mu. This shows that the cultivation scale in our survey sample is polarized. There are a lot of both small-scale farmers and large-scale farmers. However, the majority of people who answered the survey were those who farmed 0–3 mu. This indicates that small-scale farmers in our sample might experience disadvantages in bargaining power. This shows how vital the "company + farmer" model is for coordinating the supply chain in growing herbal medicine.

In terms of the topography of TCMM areas, 55.38% of the people who answered our survey work in places with mountains, hills, plateaus, or valleys. Only 0.63% operate in places with very harsh natural conditions, like deserts, gobi deserts, grasslands, or loess hilly regions. This distribution pattern supports the specific natural conditions that are needed for TCMM to grow. Unique natural conditions are very important for TCMM. These plants generally do well in places with a lot of biological resources, a lot of sunlight, and a lot of rain. The unique geological and topographical features also make it easier to grow TCMM.

This study utilized the statistical analysis capabilities of SoJump to compile data regarding the specific varieties of TCMM cultivated by respondents. The survey sample indicated that respondents cultivated up to 50 varieties of TCMM. But this number is still pretty small compared to the total number of medicinal herb varieties that can be used. Farmers most often grew these ten plants: Huangjing (Solomon's Seal), Maidong (Ophiopogon Root), Jinyinhua (Honeysuckle Flower), Touhualiao (Polygonum capitatum), Juhua (Chrysanthemum), Chuanxiong (Sichuan Lovage Root), Baiji (Bletilla Rhizome), Baishao (White Peony Root), Danshen (Salvia Root), and Baizhi (Angelica Root).

Figure 5.1 shows the top 10 most commonly grown medicinal herb species among the study sample. This is to show visually the main types of medicinal herbs that farmers grow. Figure 5.1 shows that Huangjing (Solomon's Seal), Maidong (Ophiopogon Root), Jinyinhua (Honeysuckle Flower), Touhualiao (Polygonum capitatum), and Juhua (Chrysanthemum) appeared 32, 29, 28, 26, and 24 times, respectively. This means that these are the five most commonly grown medicinal herbs among the respondents who took our survey. They probably also show herbs that are in high demand on the market and have cultivation methods that are well-established.

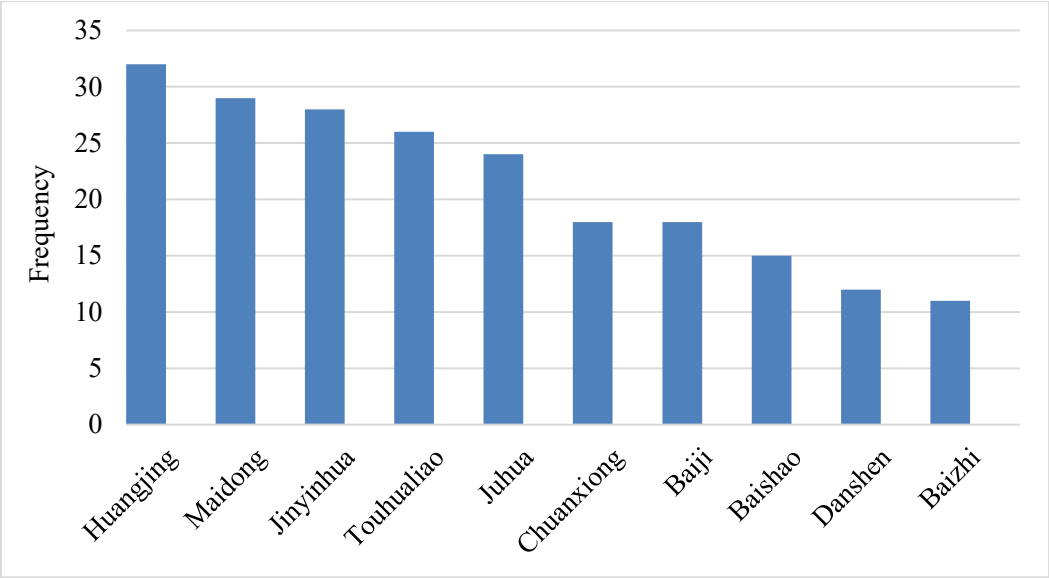


Figure 5.1 Top 10 most frequently cultivated TCMM by respondents

Furthermore, since established literature has documented the role of farmers' resource endowments in influencing crop quality, we also collected preliminary statistics on farmers' resource endowment levels. The specific details are reported in the final section of Table 5.2.

In our survey sample, we found that 41.46% of respondents were members of rural cooperatives. Even though this is a large number, 58.54% of people who answered did not join rural cooperatives. This information shows that some people who answered the survey know that working together in agriculture can help protect their rights and interests. But the government still needs to promote the role of rural cooperatives and get more farmers to join.

When it comes to the actual number of people in a household who could work on a TCMM farm, 40.51% of the surveyed farming households only had two people who could do so. Our survey sample shows that the average number of people in a household who can practically help with growing medicinal herbs is low. This also indicates that in China, family planning policies mean that households do not have a lot of people living in them. For farming families, it is clear how important and necessary it is to use farming machines instead of doing things by hand.

We looked at farmers' own social capital by examining how well they could handle risks and make things. In our sample, 60.44% of those who answered had bought agricultural insurance. 39.56% of those who answered said they had never been in agricultural insurance. This means that most of the people who answered the survey understand how important it is to transfer risks through agricultural insurance. 43.04% of respondents had borrowed or taken out loans, which is what the question was about. This demonstrates that a large number of people who answered the survey can still get money from outside sources. Overall, the farmers who

were asked about their social capital show that they do not have much of it.

Furthermore, China is a society that is all about relationships. Having certain "connections" (guanxi) is also part of a farming family's ability to grow things. In our survey, 39.24% of the people who answered said that someone in their household was a village cadre or worked for the government or a public institution. At the same time, 60.76% of those who answered said that no one in their household held such jobs. Farming families with connections tend to have more power when it comes to growing TCMM.

5.1.2 Descriptive statistics of the variables

5.1.2.1 Descriptive statistics

Based on 539 valid questionnaires collected, we conducted a descriptive analysis of the six variables involved in the empirical analysis, which comprised a total of twenty-nine measurement items. The analysis reports maximum values, minimum values, means, standard deviations, skewness, and kurtosis. Table 5.3 presents the descriptive statistics for all variables examined in this study.

Table 5.3 Descriptive statistics of variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Item	N	mean	sd	min	max	skewness	kurtosis
TA1	539	4.113	0.836	1.000	5.000	-1.399	3.222
TA2	539	4.210	0.615	1.000	5.000	-0.495	1.332
TA3	539	4.250	0.602	1.000	5.000	-0.427	1.069
TA4	539	4.087	0.717	1.000	5.000	-0.463	0.208
TS1	539	4.187	0.613	1.000	5.000	-0.324	0.694
TS2	539	4.200	0.598	1.000	5.000	-0.313	0.898
TS3	539	4.315	0.559	3.000	5.000	-0.066	-0.642
TS4	539	4.278	0.610	3.000	5.000	-0.236	-0.611
TS5	539	4.252	0.591	3.000	5.000	-0.133	-0.506
TS6	539	4.208	0.602	2.000	5.000	-0.173	-0.223
IC1	539	4.263	0.586	2.000	5.000	-0.238	0.064
IC2	539	4.221	0.629	2.000	5.000	-0.477	0.618
IC3	539	4.213	0.616	2.000	5.000	-0.263	-0.108
IC4	539	4.093	0.656	2.000	5.000	-0.454	0.600
IC5	539	4.132	0.724	1.000	5.000	-0.734	1.106
IC6	539	4.234	0.607	2.000	5.000	-0.516	1.148
DMC1	539	4.043	0.793	1.000	5.000	-0.905	1.324
DMC2	539	4.063	0.742	1.000	5.000	-0.703	0.804
DMC3	539	4.054	0.716	2.000	5.000	-0.688	0.846
DMC4	539	4.113	0.687	2.000	5.000	-0.768	1.325
DMC5	539	4.096	0.699	1.000	5.000	-0.820	1.578
GS1	539	4.065	0.715	1.000	5.000	-0.554	0.587
GS2	539	3.991	0.782	1.000	5.000	-0.638	0.401
GS3	539	4.128	0.671	2.000	5.000	-0.488	0.452
GS4	539	4.087	0.629	2.000	5.000	-0.247	0.172
QE1	539	4.243	0.571	3.000	5.000	-0.045	-0.411

QE2	539	4.254	0.549	2.000	5.000	-0.017	-0.02
QE3	539	4.249	0.576	2.000	5.000	-0.307	0.765
QE4	539	4.202	0.589	2.000	5.000	-0.135	-0.128

First, the mean reflects the central tendency of a dataset. The second column of Table 5.3 reports the mean values of the variables. The maximum and minimum mean values of the measured variables in our sample are 4.315 (*TS3*) and 3.991 (*GS2*), respectively. The item corresponding to *TS3* is: The company's technology sharing assists farmers in resolving production issues. The item corresponding to *GS2* is: Government support covers the major costs associated with new technology adoption. The mean values of *TS3* and *GS2* indicate that respondents perceive the company's technology sharing as highly beneficial in addressing technical challenges. In contrast, respondents' perception of government support covering the major costs of new technology adoption is relatively lower than that of *TS3*.

Column 3 of Table 5.3 presents the standard deviations for all twenty-nine measurement items. The maximum and minimum standard deviations among the measured variables are 0.836 *(TA1*) and 0.549 (*QE2*), respectively. Columns 4 and 5 of Table 5.3 present the maximum and minimum values of the measurement items. As a five-point Likert scale was employed in our study, the observed values for all measurement variables theoretically ranged from 1 to 5.

This study employs skewness and kurtosis to assess the normality of variables. Skewness quantifies the asymmetry of a random variable's probability distribution, indicating the extent to which the variable diverges from its mean. The skewness coefficient tells it how much and in what direction the data distribution is not normal. A skewness value that is closer to 0 means that the variable is more like a normal distribution. If the skewness value is greater than 0, it means that the variable distribution is skewed to the right. If the value is less than 0, it suggests that the variable distribution is skewed to the left. A bigger absolute skewness value implies that the variable distribution is more skewed. Non-normal distribution of variables can skew the results of multivariate analysis and make structural equation modeling less effective.

The sixth column of Table 5.3 shows how skewed the variables are, which shows how symmetrical their distributions are. *TA1* has a skewness value of -1.399, which is more than 1 in absolute value. The other 28 items possess negative skewness values, and their absolute values are all less than 1. The absolute values of skewness for our variables are mostly below 1, which means that the sample data is mostly normally distributed, even though it is slightly left-skewed (J. Hair et al., 2017).

Kurtosis is a statistical tool that looks at how steep or flat a data distribution is. We can tell if the data distribution is steeper or flatter than a normal distribution by figuring out the kurtosis coefficient. A kurtosis value of 0 means that the peak of the distribution is the same as that of a

normal distribution. A kurtosis value greater than 0 means that the distribution is steeper (leptokurtic), and a kurtosis value less than 0 means that the distribution is flatter (platykurtic).

If the absolute value of kurtosis is less than 1, it means that the sample is close to a normal distribution, just like skewness (J. Hair et al., 2017). The seventh column of Table 5.3 shows the kurtosis of the variables. The kurtosis values for *TA1*, *TA2*, *TA3*, *IC5*, *IC6*, *DMC1*, *DMC4*, and *DMC5* are all slightly above 1. The absolute kurtosis values for the other variables are all below 1. In our sample, the highest kurtosis is 3.222. The absolute kurtosis values of the other variables are either close to or less than 1. This suggests that the sample generally follows a normal distribution.

Based on the distribution characteristics of the variables, our sample mostly fits a normal distribution, which is what the PLS-SEM analysis needs. This confirms the strength and suitability of the selected analytical method for investigating the relationships among the constructs in our study.

5.1.2.2 Correlation analysis

Table 5.4 reports the correlation coefficients among the latent variables. There exists a positive correlation between the quality of TCMM (*QE*) and technology adoption (*TA*), technology sharing (*TS*), information coordination (*IC*), decision-making coordination (*DMC*), and government support (*GS*), with correlation coefficients exceeding 0.600. This finding provides preliminary evidence for the relationships between variables, indicating that technology adoption, technology sharing, information coordination, decision-making coordination, and government support can contribute to improving the quality of TCMM cultivated by farmers.

Table 5.4 Correlation analysis of latent variables

	DMC	GS	IC	QE	TA	TS
DMC	1					
GS	0.741	1				
IC	0.735	0.715	1			
QE	0.643	0.707	0.705	1		
TA	0.519	0.547	0.602	0.624	1	
TS	0.646	0.639	0.767	0.715	0.745	1

5.2 Common method bias test

Since this study relied on cross-sectional self-reported data, common method bias was a potential concern. To assess its impact, Harman's single-factor test was conducted (Podsakoff et al., 2003). All measurement items were entered into an unrotated principal component analysis, and factors with eigenvalues greater than 1 were extracted.

Table 5.5 reveals that the unrotated factor analysis extracted four factors with eigenvalues greater than 1. However, the first factor accounted for 53.71% of the total variance, exceeding the critical threshold of 50%. Consequently, the results of Harman's single-factor test suggest the presence of common method bias in the data.

Table 5.5 Harman one-way test results (unrotated factorial solution)

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	16.65	53.711	53.711	16.65	53.711	53.711
2	2.234	7.207	60.918	2.234	7.207	60.918
3	1.226	3.956	64.874	1.226	3.956	64.874
4	1.154	3.722	68.596	1.154	3.722	68.596
5	0.874	2.819	71.415			
6	0.750	2.419	73.833			
7	0.707	2.280	76.114			
8	0.582	1.877	77.991			
9	0.563	1.815	79.805			
10	0.483	1.557	81.362			
11	0.468	1.508	82.871			
12	0.408	1.316	84.187			
13	0.398	1.283	85.470			
14	0.385	1.243	86.714			
15	0.357	1.152	87.866			
16	0.329	1.061	88.927			
17	0.322	1.040	89.967			
18	0.303	0.977	90.944			
19	0.294	0.947	91.891			
20	0.285	0.919	92.811			
21	0.282	0.908	93.719			
22	0.259	0.835	94.554			
23	0.242	0.781	95.335			
24	0.236	0.762	96.097			
25	0.222	0.715	96.812			
26	0.197	0.636	97.448			
27	0.184	0.593	98.041			
28	0.183	0.590	98.632			
29	0.165	0.533	99.165			
30	0.140	0.452	99.617			
31	0.119	0.383	100.000			

It is important to note that the Harman one-way test is a highly sensitive diagnostic method with thresholds that are largely derived from academic practice and are not strictly statistical judgments (Podsakoff et al., 2003). The results of the moderated effects test in this study (see Section 5.5.3) showed that all interaction terms reached a statistically significant level, whereas common method bias typically exhibits an inhibitory rather than a facilitatory effect on

interaction effects (Siemsen et al., 2010). Therefore, the significant presence of moderating effects can be considered as indirect evidence that common method bias did not severely distort the relationships between variables. In addition, there were four factors with eigenvalues greater than 1 in the unrotated solution, and the first factor did not dominate all of the variance, which also suggests that there is still sufficient differentiation between the constructs.

Combining the procedural controls in the questionnaire design phase (anonymity, random ordering of the questions), the results of the moderated effects test, and the multifactor structural characteristics, this study concludes that the threat of common methodological bias to the conclusions of the subsequent analyses is within acceptable limits.

5.3 Reliability and validity analysis of the measurement model

This section employs SmartPLS 4.0 to assess the reliability and validity of the measurement model. Reliability refers to the degree of consistency of the measurement variables across the intended dimensions, i.e., the trustworthiness of the measurements. Validity denotes the extent to which the measurement variables accurately reflect the target constructs, or the ability to avoid systematic or non-random errors, which can be understood as the effectiveness of the measurements.

5.3.1 Reliability analysis

Reliability analysis is used to examine the internal consistency and stability of a scale. This study employs Cronbach's α coefficient and composite reliability (Rho_A and Rho_C) as evaluation criteria. Generally, a Cronbach's α value greater than 0.700 indicates good scale reliability (Nunnally & Bernstein, 1994). Composite reliability, calculated from factor loadings, is an indicator of internal consistency reliability. Although both are used to assess the internal consistency of a scale, composite reliability is considered to perform better than the traditional Cronbach's α coefficient (J. Hair et al., 2017).

Panel A of Table 5.6 presents the preliminary reliability and validity test results of the scale used in this study. As shown in column (1) of Table 5.6, the maximum and minimum Cronbach's α values for all constructs are 0.931 and 0.874, respectively, exceeding the recommended threshold of 0.700. The minimum values for composite reliability measures Rho_A and Rho_C are 0.878 and 0.914, respectively, also surpassing 0.700. Furthermore, all composite reliability values remain below 0.950, indicating limited likelihood of compromised discriminant validity among the measurement items (J. F. Hair et al., 2019).

Table 5.6 Reliability and validity assessment of constructs

Panel A: Reliability and validity assessment of constructs

Construct	Cronbach's alpha	Rho_A	Rho_C	AVE
DMC	0.931	0.936	0.948	0.784
GS	0.879	0.881	0.917	0.733
IC	0.915	0.917	0.934	0.701
QE	0.907	0.908	0.935	0.782
TA	0.874	0.878	0.914	0.728
TS	0.906	0.908	0.928	0.681

Panel B: Summary of factor loadings

Outer loadings			Outer loadings
TA1 <- TA	0.814	IC6 <- IC	0.828
TA2 <- TA	0.911	DMC1 <- DMC	0.841
TA3 <- TA	0.895	DMC2 <- DMC	0.883
TA4 <- TA	0.786	DMC3 <- DMC	0.908
TS1 <- TS	0.814	DMC4 <- DMC	0.908
TS2 <- TS	0.823	DMC5 <- DMC	0.887
TS3 <- TS	0.824	GS1 <- GS	0.871
TS4 <- TS	0.848	GS2 <- GS	0.847
TS5 <- TS	0.825	GS3 <- GS	0.872
TS6 <- TS	0.817	GS4 <- GS	0.835
IC1 <- IC	0.837	QE1 <- QE	0.872
IC2 <- IC	0.844	QE2 <- QE	0.906
IC3 <- IC	0.877	QE3 <- QE	0.899
IC4 <- IC	0.808	QE4 <- QE	0.858
IC5 <- IC	0.828		

In summary, preliminary results demonstrate excellent internal consistency reliability of our measurement model. This confirms that all measurement scales designed for the “company + farmer” TCMM cultivation model exhibit high internal consistency and excellent reliability, capable of stably and reliably measuring each latent variable.

5.3.2 Validity analysis

Validity analysis aims to examine whether the measurement tool can truly and accurately measure the theoretical constructs designed for the research. This study primarily conducts the assessment from two aspects: convergent validity and discriminant validity.

5.3.2.1 Convergent validity analysis

Convergent validity (also known as aggregated validity) emphasizes that measurement items which should theoretically belong to the same factor do indeed load onto that factor. This research comprehensively assesses it through the average variance extracted (hereafter, AVE) and factor loadings.

The AVE measures a latent variable's explanatory power regarding the variance of its measurement indicators. A higher AVE value indicates that the construct possesses greater reliability and convergent validity.

We used the AVE to preliminarily evaluate the convergent validity of the measurement model. The fourth column of Table 5.6 displays the average variance extracted for the measurement model. The minimum AVE value for the six constructs in this study is 0.681, which exceeds the threshold of 0.500 (Bagozzi & Yi, 1988). This indicates that each latent variable can explain more than half of the variance in its corresponding items. Our measurement model meets the standard for convergent validity and does not need any changes.

Panel B of Table 5.6 presents the factor loadings of the measurement model. As shown in the table, all measurement items exhibit loadings well above the acceptable threshold of 0.700 on their respective constructs, demonstrating excellent convergent validity.

5.3.2.2 Discriminant validity analysis

Discriminant validity emphasizes that measurement items which should not theoretically belong to the same factor indeed load onto different factors. Drawing on prior research (J. Hair et al., 2017), this study comprehensively assesses discriminant validity using cross-loadings, the Fornell-Larcker criterion, and the Heterotrait-Monotrait Ratio.

Cross-loadings refer to the correlation coefficients between a measurement variable and constructs to which it does not correspond. The criterion for establishing cross-loadings is that the outer loading of a measurement variable on its corresponding construct must be greater than its cross-loadings (J. Hair et al., 2017).

Table 5.7 reports the test results of the cross-loadings. The bolded values represent the outer loadings, while the other values are the cross-loadings. It can be observed that the outer loadings are all greater than their respective cross-loadings, thus meeting the standard for cross-loadings (Chin, 1998).

Table 5.7 Cross-loadings analysis

	DMC	GS	IC	QE	TA	TS
DMC1	**0.841**	0.645	0.641	0.506	0.460	0.569
DMC2	**0.883**	0.637	0.622	0.550	0.431	0.553
DMC3	**0.908**	0.687	0.648	0.540	0.459	0.524
DMC4	**0.908**	0.658	0.681	0.610	0.476	0.588
DMC5	**0.887**	0.655	0.658	0.628	0.472	0.618
GS1	0.658	**0.871**	0.612	0.598	0.461	0.535
GS2	0.655	**0.847**	0.623	0.551	0.402	0.483
GS3	0.605	**0.872**	0.635	0.635	0.471	0.590
GS4	0.623	**0.835**	0.581	0.630	0.531	0.572
IC1	0.619	0.616	**0.837**	0.638	0.531	0.723

IC2	0.605	0.579	**0.844**	0.571	0.473	0.644
IC3	0.637	0.642	**0.877**	0.629	0.562	0.679
IC4	0.571	0.588	**0.808**	0.550	0.516	0.605
IC5	0.633	0.592	**0.828**	0.526	0.413	0.539
IC6	0.625	0.573	**0.828**	0.609	0.515	0.644
QE1	0.572	0.620	0.608	**0.872**	0.540	0.634
QE2	0.591	0.652	0.652	**0.906**	0.553	0.638
QE3	0.576	0.625	0.632	**0.899**	0.570	0.657
QE4	0.536	0.602	0.599	**0.858**	0.543	0.601
TA1	0.414	0.427	0.472	0.473	**0.814**	0.587
TA2	0.428	0.461	0.499	0.541	**0.911**	0.651
TA3	0.437	0.471	0.507	0.564	**0.895**	0.681
TA4	0.489	0.502	0.571	0.542	**0.786**	0.615
TS1	0.490	0.498	0.555	0.526	0.649	**0.814**
TS2	0.503	0.505	0.561	0.575	0.719	**0.823**
TS3	0.502	0.503	0.652	0.604	0.603	**0.824**
TS4	0.584	0.550	0.689	0.626	0.599	**0.848**
TS5	0.538	0.524	0.635	0.591	0.591	**0.825**
TS6	0.572	0.577	0.692	0.613	0.541	**0.817**

However, the effectiveness of cross-loadings in variance-based SEM has been questioned. J. Henseler et al. (2015) pointed out that cross-loadings are not sensitive enough in detecting issues of discriminant validity. Therefore, we proceeded to use two additional indicators to evaluate the discriminant validity of the measurement variables.

The Fornell-Larcker criterion requires that the square root of a construct's AVE must be greater than its correlation coefficients with any other constructs (Fornell & Larcker, 1981). Table 5.8 presents the test results for the Fornell-Larcker criterion. The square roots of the AVE (shown in bold on the diagonal) are all greater than any correlation coefficient in their respective rows and columns. For example, the square root of the AVE for *DMC* (0.886) is greater than its correlation coefficients with *GS*, *IC*, *QE*, *TA*, and *TS* (0.741, 0.735, 0.643, 0.519, and 0.646, respectively).

Table 5.8 Assessment of the fornell-larcker criterion

	DMC	GS	IC	QE	TA	TS
DMC	**0.886**					
GS	0.741	**0.856**				
IC	0.735	0.715	**0.837**			
QE	0.643	0.707	0.705	**0.884**		
TA	0.519	0.547	0.602	0.624	**0.853**	
TS	0.646	0.639	0.767	0.715	0.745	**0.825**

Therefore, the discriminant validity of the measurement scale in this study meets the requirements of the Fornell-Larcker criterion. However, the application of the Fornell-Larcker criterion also has limitations, as empirical researchers might potentially misinterpret discriminant validity (J. Henseler et al., 2015). Consequently, we further assessed discriminant validity using the Heterotrait-Monotrait Ratio.

J. Henseler et al. (2015) pointed out that the Heterotrait-Monotrait ratio can effectively

detect the absence of discriminant validity with a high sensitivity rate. The Heterotrait-Monotrait ratio is defined as the ratio of the mean of correlations between indicators across different constructs to the mean of correlations between indicators within the same construct. Discriminant validity is established when there is sufficient distinction between constructs. Hence, heterotrait-heteromethod correlations should be small. Specifically, discriminant validity is supported if the Heterotrait-Monotrait ratio value between two constructs does not exceed 0.850. Alternatively, when the constructs are conceptually similar, the Heterotrait-Monotrait ratio should not be greater than 0.900 (J. Henseler et al., 2015).

Table 5.9 presents the results of the Heterotrait-Monotrait ratio assessment. It can be observed that the highest Heterotrait-Monotrait ratio value in our measurement model is 0.839, which is below the threshold of 0.850. This indicates that all Heterotrait-Monotrait ratio values between the latent constructs in our measurement model are lower than the stringent criterion of 0.850. The results of the Heterotrait-Monotrait ratio analysis support the acceptability of discriminant validity of our measurement constructs.

Table 5.9 Assessment of the heterotrait-monotrait ratio

	DMC	GS	IC	QE	TA	TS
DMC						
GS	0.821					
IC	0.796	0.798				
QE	0.696	0.789	0.77			
TA	0.575	0.62	0.67	0.699		
TS	0.699	0.711	0.835	0.787	0.839	

In summary, the outcomes from the three evaluations—cross-loadings, the Fornell-Larcker criterion, and the Heterotrait-Monotrait ratio—collectively and consistently indicate that the constructs representing the distinct dimensions of the “company + farmer” TCMM cultivation model in our study are well differentiated, thereby affirming adequate discriminant validity.

5.4 Collinearity diagnosis

In SEM, when an endogenous latent variable is concurrently affected by several exogenous latent variables, robust statistical correlations may be present among these exogenous variables, a situation referred to as collinearity (J. Hair et al., 2017). To guarantee that collinearity does not influence the regression outcomes, this study performed tests on both the measurement model and the structural model. The outer model and inner model were used to find collinearity in particular.

5.4.1 Outer model

We used the Variance Inflation Factor (VIF) to check for collinearity. The VIF measures how closely related the predictor variables are to each other, showing how significantly the observed values of these variables are related to each other. With reference to established research, a VIF value below 5 indicates the absence of collinearity issues in the structural model (J. F. Hair et al., 2011).

Table 5.10 reports the collinearity statistics for the outer model. The outer VIF values for all measurement items range from 1.635 to 3.801, which are well below the threshold of 5. This indicates the absence of severe collinearity issues among the measurement indicators.

Table 5.10 Assessment of variance inflation factor in the outer model

Item	VIF	Item	VIF
DMC1	2.488	QE1	2.553
DMC2	3.238	QE2	3.177
DMC3	3.801	QE3	3.035
DMC4	3.786	QE4	2.401
DMC5	3.229	TA1	2.026
GS1	2.558	TA2	3.573
GS2	2.351	TA3	3.085
GS3	2.348	TA4	1.635
GS4	1.972	TS1	2.324
IC1	2.436	TS2	2.354
IC2	2.623	TS3	2.268
IC3	3.096	TS4	2.549
IC4	2.247	TS5	2.226
IC5	2.429	TS6	2.174
IC6	2.285		

5.4.2 Inner model

Table 5.11 reports the collinearity statistics for the inner model. The inner VIF values for the antecedent latent variables in explaining the endogenous variable "*QE*" range from 2.412 (*TA*) to 4.995 (*GS* × *TS*). The VIF value for the *GS* × *TS* interaction is close to 5, but it is still in the acceptable range. This means that there are not any major collinearity problems with the independent variables in our structural model, and the model estimation results are stable.

Table 5.11 Assessment of variance inflation factor in the inner model

	VIF
DMC -> QE	3.090
GS -> QE	2.683
GS x DMC -> QE	2.977
GS x IC -> QE	3.238
GS x TA -> QE	3.173
GS x TS -> QE	4.995
IC -> QE	4.147

TA -> QE	2.412
TS -> QE	3.998

5.5 Hypothesis testing

This study implements PLS-SEM and SmartPLS 4.0 software to examine at how the "company + farmer" model affects the quality of TCMM. The PLS-SEM method is good for doing research that is exploratory, developing theories, and working with complicated causal models. This method fits the goals and data of this study perfectly, so it is a good way to test our hypotheses.

This research utilizes Bootstrap resampling methods to evaluate the statistical significance of path coefficients, focusing on the mechanisms through which the "company + farmer" model improves the quality of TCMM and the moderating effect of government support. T-statistics and confidence intervals from 5,000 Bootstrap samples are used to figure out if a coefficient is significant. The traditional P-value thresholds for statistical significance are 0.01, 0.05, and 0.10, which show levels of significance that get lower as the number gets higher. To keep a stricter standard for statistical significance, we set the level of significance at 0.05.

5.5.1 Overall model fit and explanatory power assessment

We examined the model's overall goodness of fit and predictive power before checking specific pathways. The model's goodness of fit (R^2) shows how much of the variance in an endogenous construct can be explained by its predictor constructs. R^2 ranges from 0 to 1, with higher values indicating greater explanatory power (J. F. Hair et al., 2011). Different fields usually use different R^2 standards. In business research, we often use R^2 thresholds of 0.67, 0.33, and 0.19 as indicators of how well a model explains something, from strong to weak (Jörg Henseler et al., 2009).

The R^2 and adjusted R^2 values for the core endogenous latent variable "TCMM enhancement (*QE*)" are 0.668 and 0.662, respectively, based on the extent to which our model fits the data. The two goodness-of-fit metrics are both very close to 0.67. This means that the model's government support, technology adoption, technology sharing, information coordination, decision-making coordination, and four interaction terms together explain 66.8% of the variance in *QE*. This shows that the model does a good job of showing the main factors that affect the quality of Chinese herbal medicine when using the "company + farmer" model.

This research employs the PLSpredict methodology established by Shmueli et al. (2016) to

evaluate the model's predictive capability. The PLSpredict procedure employs training and holdout sampling to produce and assess predictions based on PLS path model estimations. The SmartPLS software now has the PLSpredict algorithm, which lets researchers get k-fold cross-validated prediction errors and summary statistics of prediction errors. These include the Root Mean Square Error (RMSE), the Mean Absolute Error (MAE), and the Mean Absolute Percentage Error (MAPE). This makes it easier for researchers to check how accurately their PLS path models predict both manifest and latent variables.

Table 5.12 reports the results generated by the PLSpredict algorithm. The calculated $Q^2_{predict}$ values are all greater than zero (*QE1*-*QE4*: 0.449-0.530), indicating that the predictive power of the PLS-SEM model exceeds the mean value of the training sample and surpasses the most naïve benchmark (Shmueli et al., 2019).

Table 5.12 PLSpredict algorithm results

	$Q^2_{predict}$	PLS-SEM_RMSE	PLS-SEM_MAE	LM_RMSE	LM_MAE	IA_RMSE	IA_MAE
QE1	0.478	0.413	0.284	0.418	0.286	0.571	0.476
QE2	0.530	0.377	0.261	0.395	0.272	0.549	0.46
QE3	0.517	0.401	0.270	0.415	0.275	0.577	0.472
QE4	0.449	0.438	0.284	0.449	0.304	0.59	0.469

Subsequently, a comparison was conducted between the PLS-SEM model, a naïve indicator—the average prediction benchmark (IA), and a conservative linear model prediction benchmark (LM) based on their loss values. A lower loss value indicates superior out-of-sample predictive performance of the model (Liengaard et al., 2021).

With reference to prior research (P. N. Sharma et al., 2023), the predictive accuracy of different models was compared. Table 5.13 and 5.14 report the results of the cross-validated predictive ability test (hereafter, CVPAT) for the predictive power of the core latent variables in the model.

Table 5.13 CVPAT LV summary-PLS-SEM vs. Indicator average (IA)

	PLS loss	IA loss	Average loss difference	t value	p value
QE	0.166	0.327	-0.161	12.538	0.000
Overall	0.166	0.327	-0.161	12.538	0.000

Table 5.14 CVPAT LV summary-PLS-SEM vs. Linear model (LM)

	PLS loss	LM loss	Average loss difference	t value	p value
QE	0.166	0.176	-0.01	1.777	0.076
Overall	0.166	0.176	-0.01	1.777	0.076

The PLSpredict analysis revealed that the RMSE and MAE values for predictions on all *QE* items generated by the PLS-SEM model were lower than the corresponding benchmark values from both the LM and the IA. Furthermore, the CVPAT demonstrated that the prediction error of the PLS model was significantly lower than that of the IA model (mean loss difference

= -0.161, $p < 0.001$). Although the PLS model's prediction error was lower than that of the LM model according to the CVPAT, this difference was not statistically significant. In summary, these results provide evidence for the model's superior out-of-sample predictive performance.

5.5.2 Results of direct effects testing

Bootstrapping is a resampling procedure that involves repeatedly drawing random samples from the original dataset with replacement to create numerous bootstrap samples. This approach facilitates the estimation of the sampling distribution of a statistic and is especially useful for evaluating the stability and significance of model parameters. The Bootstrapping procedure in SmartPLS 4.0 is employed to carefully check the path coefficients and see if they are statistically significant. This gives a strong foundation for testing hypotheses within the structural model.

The path coefficient is like the regression coefficient in regression analysis because it shows how different parts of a model are related to each other. A coefficient exceeding zero indicates a positive correlation between the two variables, with a higher value reflecting a more robust degree of correlation (J. F. Hair et al., 2019). A p-value for the coefficient test is usually given along with the path coefficient to figure out if the path coefficient is statistically significant.

Direct effects show how an independent variable directly affects a dependent variable. Using bootstrapping, we have presented the hypothesis testing results for the path relationships in Table 5.15 and Figure 5.2. Based on the bootstrapping analysis results provided in Table 5.15, the proposed direct effect hypotheses are systematically evaluated. The decision-making criterion is as follows: a path is considered statistically significant if the absolute value of the t-statistic is greater than 1.96 and the p-value is less than 0.05.

Table 5.15 Results of hypothesis testing

		Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
(1)	TA -> QE	0.128	0.126	0.045	2.87	0.004
(2)	TS -> QE	0.177	0.176	0.063	2.799	0.005
(3)	IC -> QE	0.164	0.167	0.068	2.42	0.016
(4)	DMC -> QE	0.139	0.135	0.059	2.345	0.019
(5)	GS -> QE	0.316	0.319	0.071	4.454	0.000
(6)	GS x TA -> QE	0.017	0.01	0.048	0.361	0.718
(7)	GS x TS -> QE	-0.135	-0.133	0.069	1.963	0.050
(8)	GS x IC -> QE	0.039	0.051	0.066	0.598	0.550
(9)	GS x DMC -> QE	0.179	0.174	0.059	3.019	0.003

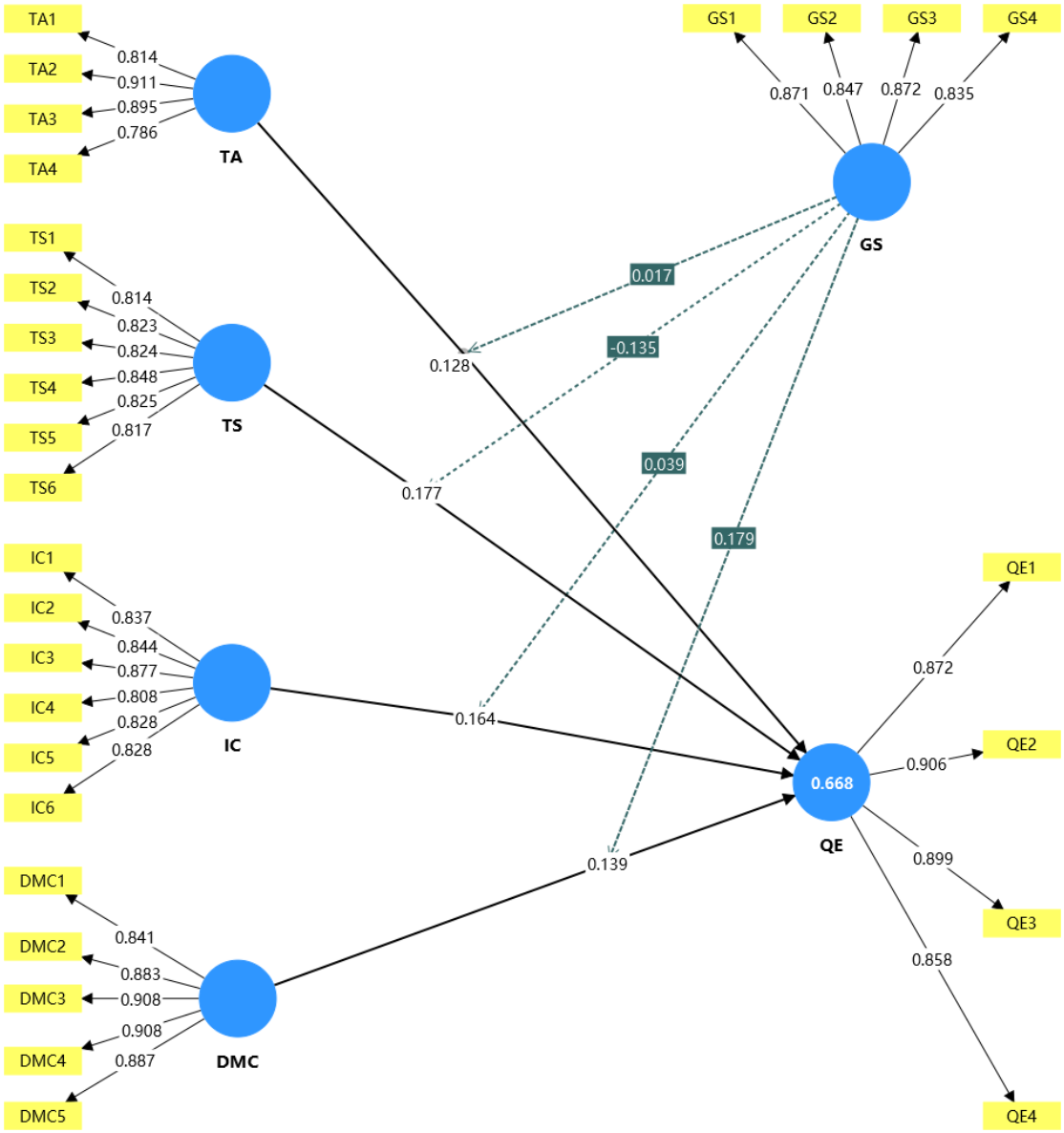


Figure 5.2 Evaluation results of the structural model

Hypothesis H1: The adoption of the company's cultivation techniques by farmers exerts a positive influence on the quality of TCMM.

The first row of Table 5.15 reports the results for the effect of technical adoption (*TA*) on quality of TCMM (*QE*). Technical adoption has a significant positive influence on quality of TCMM (path coefficient β = 0.128, T = 2.870, P = 0.004). The result is statistically significant at the 1% level (P < 0.01). Therefore, Hypothesis H1 is supported. This finding indicates that, under the "company + farmer" TCMM cultivation model, the active adoption of modern cultivation techniques shared by the company by farmers can directly and effectively promote the quality improvement of Chinese medicinal raw materials.

Hypothesis H2: The company's sharing of agricultural techniques with farmers positively influences the quality of TCMM.

The second row of Table 5.15 reports the results for the effect of technical sharing (*TS*) on the quality of TCMM (*QE*). Technical sharing has a significant positive influence on quality (path coefficient $\beta = 0.177$, $T = 2.799$, $P = 0.005$), which is statistically significant at the 1% level ($P < 0.01$). Therefore, Hypothesis H2 is not rejected. This finding confirms that, within the "company + farmer" cultivation model, the company's provision of technical training, demonstration, and dissemination to farmers constitutes a crucial internal mechanism for elevating quality standards across the TCMM industry chain.

Hypothesis H3: Information coordination within supply chain quality coordination positively influences the quality of TCMM.

The third row of Table 5.15 shows the results of the effect of information coordination (*IC*) on the quality of TCMM (*QE*). Information coordination has a strong positive effect on the quality of TCMM (path coefficient $\beta = 0.164$, $T = 2.420$, $P = 0.016$), which is statistically significant at the 5% level ($P < 0.05$). Thus, Hypothesis H3 is not rejected. This finding suggests that timely, straightforward, and two-way communication between the company and farmers about market data, production data, and quality feedback is necessary for working together to improve the quality of TCMM.

Hypothesis H4: Decision-making coordination within supply chain quality coordination positively influences the quality of TCMM.

The fourth row of Table 5.15 reports the results for the effect of decision-making coordination (*DMC*) on the quality of TCMM (*QE*). Decision-making coordination has a significant positive influence on quality (path coefficient $\beta = 0.139$, $T = 2.345$, $P = 0.019$), which is statistically significant at the 5% level ($P < 0.05$). Therefore, Hypothesis H4 is supported. This result demonstrates that collective participation and joint decision-making between the company and farmers in areas such as production planning, quality standard setting, and risk response effectively ensure that the quality of the TCMM cultivated by farmers meets expectations.

In summary, the above analysis collectively demonstrates that within the "company + farmer" model for cultivating TCMM, technical adoption, technical sharing, information coordination, and decision-making coordination all play a positive role in improving quality. All hypotheses proposed in this study (H1–H4) are not rejected.

5.5.3 Results of the moderating effect tests

Government support in areas such as policy guidance, funding subsidies, and platform development serves as a crucial external driving force for promoting quality improvement of TCMM within the "company + farmer" cultivation model. The moderating effect analysis aims to examine whether government support (*GS*) strengthens the relationships between the four collaborative variables (*TA*, *TS*, *IC*, *DMC*) and the quality of TCMM (*QE*). The decision-making criteria remain consistent with those used for the direct effects.

To further visualize the significant moderating effects, this study constructed simple slope analysis plots and also reported the results of the conditional direct effects.

Hypothesis H5: Government support (*GS*) positively moderates the effect of technical adoption (*TA*) on the quality of TCMM (*QE*).

Table 5.16 reports the direct effects of the independent variables (*TA*, *TS*, *DMC*, *IC*) on the dependent variable (*QE*) at different levels of the moderating variable (*GS*), namely, at +1 standard deviation, -1 standard deviation, and the mean. As shown in the first column of Table 5.16, a one standard deviation increase in *GS* leads to an increase of 0.146 in the path coefficient between *TA* and *QE*, while a one standard deviation decrease in *GS* leads to an increase of 0.111 in the same path coefficient. This indicates that the magnitude of the moderating effect is minimal, suggesting that *GS* does not exert a significant moderating effect.

Table 5.16 Conditional direct effects

	(1) TA -> QE	(2) TS -> QE	(3) IC -> QE	(4) DMC -> QE
GS at +1 SD	0.146	0.042	0.204	0.318
GS at -1 SD	0.111	0.312	0.125	-0.04
GS at Mean	0.128	0.177	0.164	0.139

The sixth row of Table 5.15 reports the moderating effect of government support (*GS*) on the relationship between technical adoption (*TA*) and the quality of TCMM (*QE*). The path coefficient for the interaction term ($GS \times TA \rightarrow QE$) is $\beta = 0.017$, with T = 0.361 and P = 0.718. The P-value is well above 0.05, and the T-statistic is less than 1.96, indicating that the moderating effect is not statistically significant.

Figure 5.3 presents the results of the simple slope analysis. The three lines, representing high, medium, and low levels of government support, are almost parallel and overlapping. This indicates that the effect of technical adoption behavior on the quality of TCMM is relatively independent and is not significantly moderated by changes in the level of government support. This phenomenon may be attributed to the inherent objectivity of technological utility; once adopted, the resulting improvement in the quality of TCMM remains relatively stable.

Consequently, Hypothesis H5 is rejected.

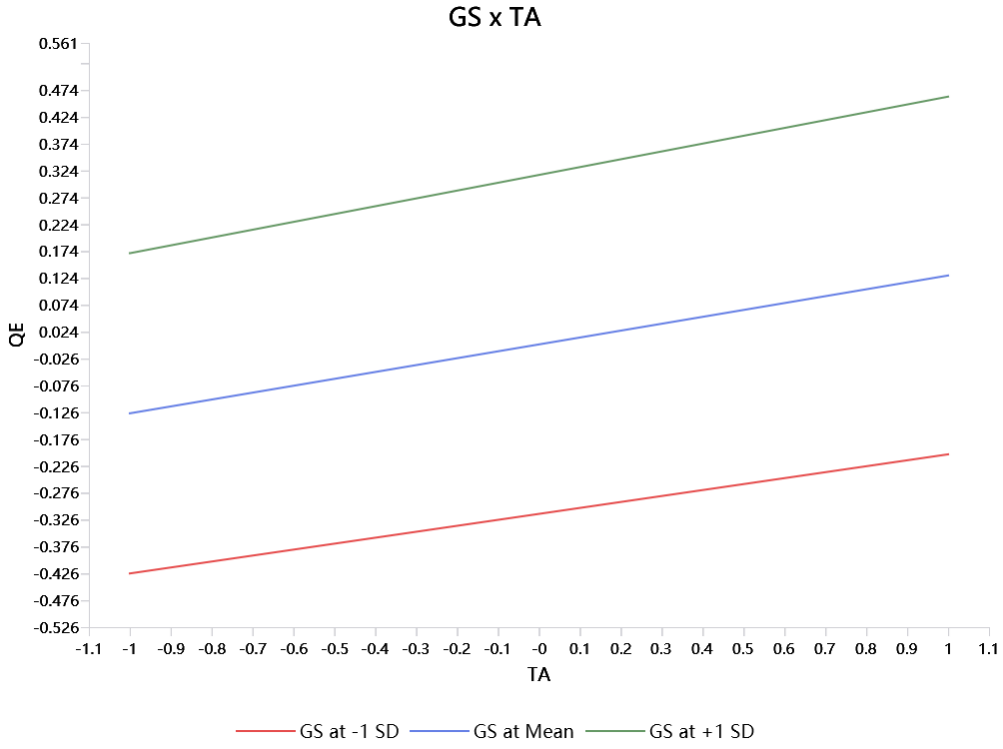


Figure 5.3 Slope chart for GS×TA

Hypothesis H6: Government support (*GS*) positively moderates the effect of technical sharing (*TS*) on the quality of TCMM (*QE*).

According to the results presented in the second column of Table 5.16, a one standard deviation increases in government support (*GS*) leads to an increase of 0.042 in the path coefficient between technical sharing (*TS*) and quality (*QE*), while a one standard deviation decrease in *GS* leads to an increase of 0.312 in the same path coefficient. This pattern indicates that the effect size is very weak (0.042) when *GS* is high, but relatively strong (0.312) when *GS* is low. These results demonstrate that *GS* exerts a negative moderating effect on the relationship between *TS* and *QE*. Specifically, higher levels of *GS* weaken the influence of *TS* on *QE*, whereas lower levels of *GS* strengthen this influence.

The seventh row of Table 5.15 reports the moderating effect of government support (*GS*) on the relationship between technical sharing (*TS*) and the quality of TCMM (*QE*). The interaction terms path coefficient ($GS \times TS \rightarrow QE$) is $\beta = -0.135$, with $T = 1.963$ and $P = 0.050$. This finding is at the limit of statistical significance ($P = 0.05$). But it's important to note that the influence is negative, which goes against what we thought at first.

Figure 5.4 presents the results of the simple slope analysis, clearly illustrating the pattern of this counterintuitive effect. When the level of government support is low (-1 SD), technical

sharing (*TS*) exhibits a strong positive effect on the quality of TCMM (*QE*), as indicated by the steep upward slope of the line. Conversely, when the level of government support is high (+1 SD), the positive effect of *TS* is markedly attenuated, with the line becoming flatter and even showing a slight downward trend. This implies that, rather than strengthening the positive impact of technical sharing, government support demonstrates a significant weakening effect.

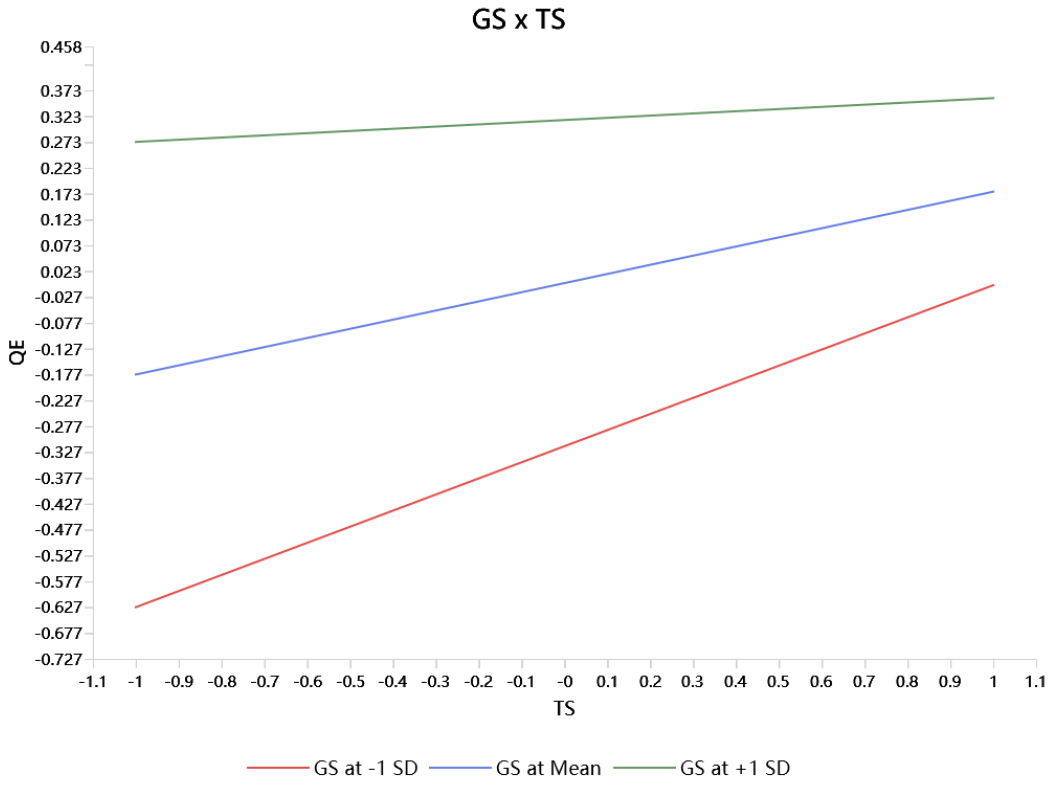


Figure 5.4 Slope chart for GS×TS

An explanation consistent with the practice of agricultural industrialization in China is that excessive or perfunctory government intervention (such as campaign-style, one-size-fits-all technical extension mandates) may crowd out the spontaneous, endogenous vitality of technical exchange between the company and the farmers—which is based on long-term coordination, trust, and mutual benefit—rendering it more procedural and less efficient. Consequently, Hypothesis H6 is not supported, and the results reveal a significant effect in the direction opposite to what was hypothesized.

Hypothesis H7: Government support (*GS*) positively moderates the effect of information coordination (*IC*) on the quality of TCMM (*QE*).

According to the results presented in the third column of Table 5.16, a one standard deviation increases in government support (*GS*) leads to an increase of 0.204 in the path coefficient between information coordination (*IC*) and the quality of TCMM (*QE*), while a one standard deviation decrease in *GS* leads to an increase of 0.125 in the same coefficient. The

effect sizes range from 0.204 (with high *GS*) to 0.125 (with low *GS*), which shows a small difference, but the effect is a little stronger when GS is higher. This pattern suggests that *GS* may exert a weak positive moderating effect, although its statistical significance requires further examination.

The eighth row of Table 5.15 reports the moderating effect of government support (*GS*) on the relationship between information coordination (*IC*) and the quality of TCMM (*QE*). The path coefficient for the interaction term (*GS* × *IC* → *QE*) is β = 0.039, with T = 0.598 and P = 0.550. Since the P-value is substantially greater than 0.05 and the T-statistic is less than 1.96, the moderating effect is statistically non-significant.

Figure 5.5 displays the results of the simple slope analysis. The three lines, representing high, medium, and low levels of government support, are nearly parallel and overlapping. This indicates that government support does not significantly alter the strength of the relationship between information coordination and quality improvement. The effectiveness of information coordination may rely more on the market-based trust mechanism and information technology infrastructure established between the company and the farmers, rather than on direct government intervention. Therefore, Hypothesis H7 is not supported.

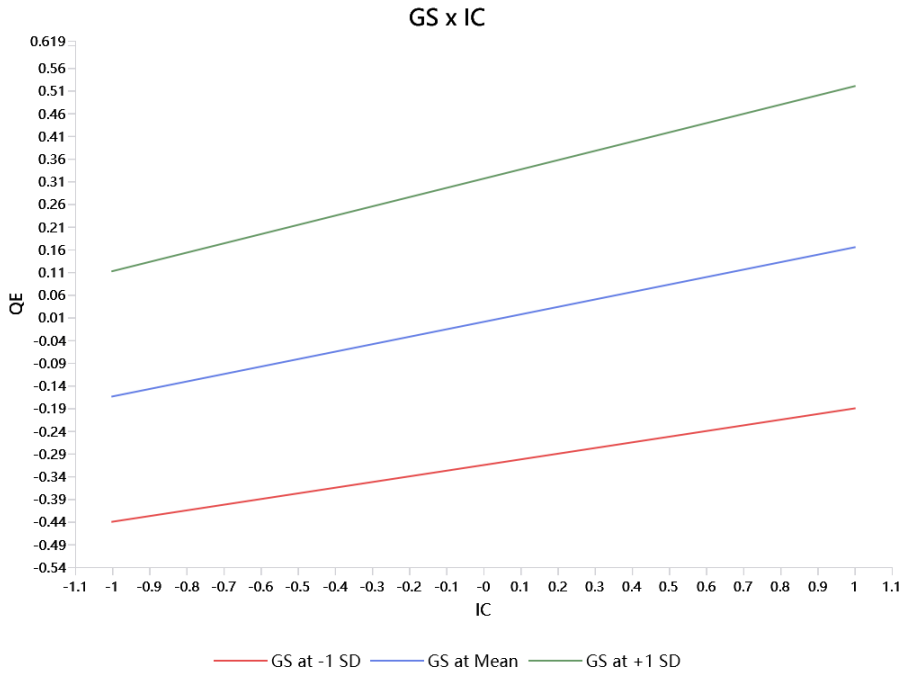


Figure 5.5 Slope chart for GS×IC

Hypothesis H8: Government support (*GS*) positively moderates the effect of decision-making coordination (*DMC*) on the quality of TCMM (*QE*).

According to the results presented in the fourth column of Table 5.16, a one standard deviation increases in government support (*GS*) leads to an increase of 0.318 in the path

coefficient between decision-making coordination (*DMC*) and the quality of TCMM (*QE*), while a one standard deviation decrease in *GS* leads to a decrease of 0.040 in the same path coefficient. This pattern demonstrates that under high *GS* conditions (+1 SD), the effect size is 0.318, indicating a relatively strong positive effect. In contrast, under low GS conditions (-1 SD), the effect size is -0.040, suggesting an effect that is negligible or slightly negative. This marked contrast indicates that *GS* likely exerts a positive moderating effect on the relationship between *DMC* and *QE*. A higher level of support from the government makes the positive effect of coordinating decision-making on the quality of TCMM even stronger.

The ninth row of Table 5.15 shows how government support (*GS*) changes the relationship between decision-making coordination (*DMC*) and the quality of TCMM (*QE*). The interaction term's path coefficient ($GS \times DMC \rightarrow QE$) is $\beta = 0.179$, with $T = 3.019$ and $P = 0.003$. This finding is extremely significant at the 1% level ($P < 0.01$). It shows that government support has a big positive effect on the link between decision-making coordination (*DMC*) and the quality of TCMM (*QE*). Hence, Hypothesis H8 is not rejected.

Figure 5.6 presents the results of the simple slope analysis. When the level of government support is high (+1 SD), the positive impact of decision-making coordination (*DMC*) on the quality of TCMM (*QE*) is strongest, as indicated by the steepest slope. Conversely, when the level of government support is low (-1 SD), the positive influence of *DMC* persists but demonstrates a weaker effect. This pattern suggests that government support can provide strong external legitimacy endorsement and resource assurance for the joint decision-making process between the company and farmers, thereby significantly enhancing the positive impact of decision-making coordination on quality improvement.

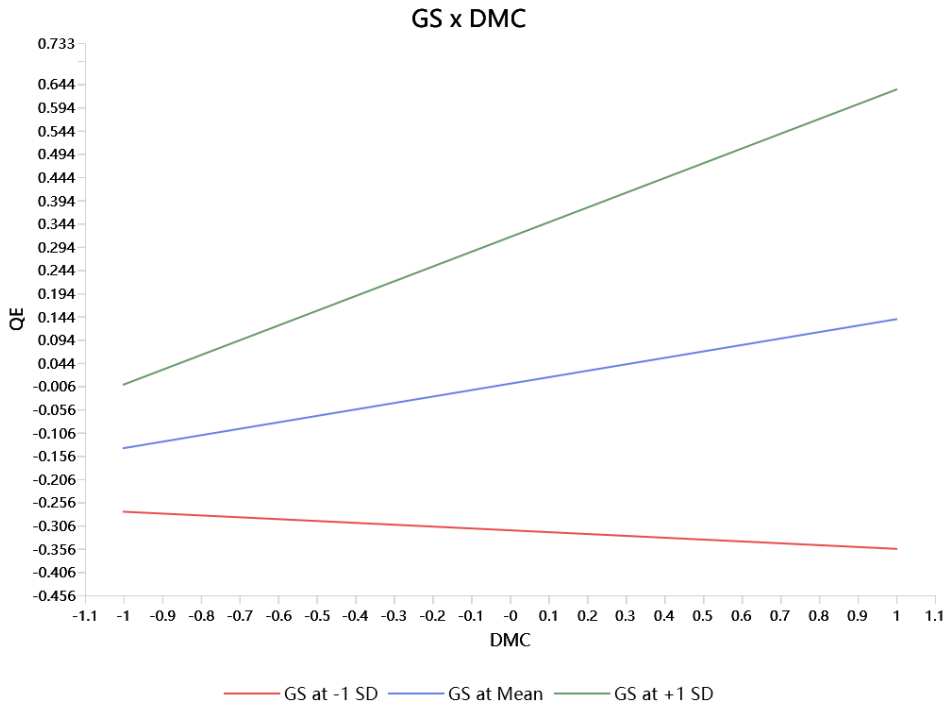


Figure 5.6 Slope chart for GS×DMC

In summary, the moderating effect analysis revealed that Hypothesis H8 was not rejected, whereas Hypotheses H5 and H7 were not supported. Notably, the result for Hypothesis H6 was significant in the opposite direction to what was predicted.

5.5.4 Summary of hypothesis testing results

In summary, among the eight path hypotheses proposed in this study, five were significantly not rejected by the statistical results (H1, H2, H3, H4, H8), two were statistically rejected (H5, H7), and one exhibited a trend in the model output that was in the opposite direction to the theoretically derived prediction (H6). All direct effect hypotheses were not rejected, whereas the moderating effect hypotheses yielded mixed results, indicating the contextual complexity of the role of government support. A summary of the hypothesis testing results is presented in Table 5.17.

Table 5.17 Summary of hypothesis testing results

Hypothesis	Hypothesis Statement	Testing Result
H1	Technical Adoption → Quality of TCMM	Not rejected
H2	Technical Sharing → Quality of TCMM	Not rejected
H3	Information Coordination → Quality of TCMM	Not rejected
H4	Decision-Making Coordination → Quality of TCMM	Not rejected
H5	Government Support × Technical Adoption → Quality of TCMM	Rejected
H6	Government Support × Technical Sharing → Quality of TCMM	Rejected
H7	Government Support × Information Coordination → Quality of TCMM	Rejected
H8	Government Support × Decision-Making Coordination → Quality of TCMM	Not rejected

5.6 Analysis of empirical results

The empirical analysis in this chapter reveals the key role of technology diffusion and supply chain coordination in improving the quality of TCMM, but more importantly, there is a differentiated mechanism behind the statistical significance. Based on the evidence of typical cases in the industry, this section will analyze the empirical results qualitatively, and systematically demonstrate the source mechanism and context-dependence of the quality enhancement dynamics in the special contractual relationship of "company+farmer".

5.6.1 Differentiation effects of dual paths of technology diffusion

The results of the direct effect test showed that both technology adoption (TA ➞ QE, $\beta = 0.128$, $p < 0.01$) and technology sharing (TS ➞ QE, $\beta = 0.177$, $p < 0.001$) had a significant positive effect on the quality of TCMM. This result validates H1 and H2 and supports the applicability of technology diffusion theory in the context of "company + farmer". However, a noteworthy finding is the difference in the strength of effect between the two paths - the contribution of technology sharing is significantly larger than that of technology adoption.

This significant difference reveals the need to further explore the mechanism of the advantage of technology sharing over technology adoption in driving quality improvement. From the perspective of transaction cost theory, technology adoption can be viewed as a unilateral decision-making behavior of farmers, and its effects are highly dependent on farmers' absorptive capacity and willingness to implement (Cohen & Levinthal, 1990). Technology sharing, on the other hand, is essentially a bilateral interaction mechanism, which not only transfers knowledge, but also reduces the uncertainty and operational risk faced by farmers in the process of technology application through continuous interaction.

These theoretical extrapolations are empirically supported by field research data. Industry

practice from Sanwotian Agricultural Company in Yunnan Province, China, shows that static technology adoption models, such as seedling supply and technical manual distribution, often fail to address the complexity and environmental uncertainty of field management (Barrett et al., 2012). In contrast, the company's comprehensive assurance mechanism has been highly effective. This mechanism involves periodic inspections by technicians, an immediate response program to unexpected agricultural situations, and a risk-pooling strategy based on guaranteed purchase (J. Y. Li & Ji, 2025). This concomitant technical guidance, embedded in the daily production process, essentially translates abstract cultivation standards into concrete practices that farmers can perceive and implement (Narrod et al., 2009). The fact that the local contracted farmers produced significantly better quality of Liliaceae herbs than the neighboring scattered farmers was due to this full-time technical support and on-site teaching interaction. This confirms the core value of the bilateral interactive technology sharing mechanism in improving the quality of agricultural products.

Although the empirical results show relatively low statistical coefficients for the technology adoption path, this does not mean that the variable lacks substantial explanatory power. The potential logical explanation for this phenomenon lies in the fact that in the current corporate-farmer governance structure, technology adoption is often not an antecedent variable that occurs independently, but rather an endogenous outcome induced by technology sharing behavior (Matuschke & Qaim, 2009). In other words, farmers' willingness to adopt new technologies is largely constrained by their institutional trust in the contracting firm and their reliance on external knowledge transfer. This finding suggests that subsequent research should go beyond the traditional view of technology sharing and adoption as simply parallel predictor variables, and instead explore the possible dynamic interaction effects or cascade mechanisms between the two (Batt, 2003).

5.6.2 Complementary logic of information transparency and decision-making in supply chain coordination

The empirical results show that both information coordination and decision-making coordination have significant positive effects on quality improvement ($\beta = 0.164$; $\beta = 0.139$), which empirically verifies the applicability of supply chain integration theory in the field of quality control of TCMM. However, in view of the typical loose coupling characteristics of the "company + farmer" model, it is particularly necessary to further investigate the path and mechanism of the above coordination mechanisms in this specific organizational form.

The government-led "Traditional Chinese Medicine Safe" platform, in which China's Shanghai Municipal Herbal Medicine Co. Ltd. participates, offers a window into the world of TCMM. With the help of blockchain technology, the platform uploads and certifies information on the entire process of planting, harvesting, processing and distribution of Chinese medicinal tablets. The value of this mechanism is first reflected in the reconstruction of trust brought about by information transparency (Saberi et al., 2019). Farmers will be more conscious of following norms when they know that their growing process will be recorded and traceable. Companies with real-time access to provenance information can more accurately schedule harvesting plans and quality control nodes (Kamble et al., 2020). By 2025, the platform will have covered TCMM plantations in 25 provinces in China, with a cumulative total of more than 540,000 pieces of uplinked traceability data (Gao, 2025).

But the value of information coordination goes beyond this. The experience of the TCMM gibberellic acid order-growing program in Yuxi City, Yunnan Province, China, suggests that the quality-enhancing effects are more pronounced when information transparency is combined with a multi-party decision-making mechanism (Simatupang & Sridharan, 2002). The project constructed a vertically linked governance structure encompassing research institutions, state-owned enterprises, professional coordination and production bases. Under this structure, pharmaceutical companies and research institutes were involved in the production decision-making process, and technical implementation plans were closely focused on key quality control indicators such as total gibberellin content, thus realizing the shift from single-link optimization to whole-chain coordination control (Reardon et al., 2009). The direct output of this coordination governance model is that the active ingredient content of gynostemma in the region has stabilized in the range of 14% to 20%, and its quality indicators are significantly better than the average level of similar production areas (W. W. Li, 2025).

The above cases reveal that information coordination constitutes the foundational structure of supply chain governance, with its core function being to address supply chain visibility challenges (Barratt & Oke, 2007). In contrast, decision-making coordination represents a higher-order governance capability that focuses on the goal of process controllability. There is a significant logical progression and complementarity between the two, for instance, decisions that are not supported by sufficient information tend to fall into the blind spot of limited rationality, and information resources that are not transformed into decision integration are not likely to produce substantial performance improvements (M. Cao & Zhang, 2011).

5.6.3 Moderating effects of government support: identification of conditional effects

The moderating effect of government support on the direct path shows a complex pattern: it significantly strengthens the role of decision coordination on quality improvement (H8 not rejected), but produces a significant negative moderating effect on technology sharing (H6 rejected). Meanwhile, its moderating effect on technology adoption (H5) and information coordination (H7) does not reach a statistically significant level. The heterogeneous distribution of the above empirical results reveals the need to further explore the boundary conditions of government support efficacy.

5.6.3.1 Reinforcement of government support for decision-making coordination

Government support significantly enhances the qualitative effects of decision coordination, a finding consistent with theoretical expectations. Given that decision coordination involves complex coordination of interests between core firms and farmers, contractual governance structure arrangements, and long-term investment of specialized assets, their effective operation often requires external institutional safeguards that go beyond discrete market transactional relationships (M. W. Peng, 2003). The extended GAP inspection of TCMM jointly conducted by Shanxi Province and Heilongjiang Province provides a case study that can be analyzed. In this case, the inspection team conducted systematic assessment from quality management, base site selection, seeds and seedlings, and provided professional guidance and compliance endorsement for joint decision-making between companies and farmers (Y. L. Ma, 2025). This service-oriented regulatory model did not replace the autonomous decision-making power of market players, but rather provided a more reliable institutional basis and stable expectation framework for the decision-making process by reducing environmental uncertainty (Henson & Caswell, 1999). This further confirms that government support can effectively promote the efficiency of coordinated decision-making across organizational actors when it is oriented towards the provision of institutional safeguards and specialized technical services.

5.6.3.2 Inhibitory effect of government support on technology sharing

The results of the empirical analysis show that government support has a significant negative moderating effect on technology sharing mechanisms, a result that is contrary to the expectations of this study. The root cause of this anomaly is mainly attributed to the imbalance between the specific implementation path and incentive structure of government intervention (Frey & Jegen, 2001). Specifically, when the public sector tends to adopt project-based management or rigid quantitative assessment to promote technology diffusion, it may trigger

the typical incentive crowding-out effect. That is, standardized technical training conducted by firms in response to the pressure of administrative targets tends to be a formalistic act of compliance, which in turn substantially substitutes for spontaneous technical exchange activities endogenous to a long-term coordinated game (DiMaggio & Powell, 1983). This mode of technology transfer, driven by external administrative forces, is fundamentally different from the subjective perception of farmers and the proactive field guidance implemented by firms to improve the overall quality performance of the supply chain, thus weakening the actual effectiveness of technology sharing.

This conclusion is consistent with the view of science and technology policy research that government intervention, if too strong, often leads to inefficient resource utilization and even substitutes for autonomous inputs by firms (J. Xu et al., 2021). The same logic applies in agricultural technology promotion. When technology sharing becomes a political task to fulfill targets and is no longer based on mutually beneficial market coordination, the intrinsic motivation of the participants decreases, and the quality and depth of sharing decreases instead.

5.6.3.3 Two scenarios where government support fails to work

The empirical results show that government support does not significantly enhance the contribution of technology adoption to quality improvement. The reasons for this phenomenon may be twofold. First, government support usually only lowers the threshold for farmers to adopt new technologies, but it does not solve the complexity and adaptability problems in the process of technology adoption (Piñeiro et al., 2020). If the promoted technologies are not effectively matched with farmers' existing cropping conditions, it is difficult to translate the financial subsidies into long-term and stable adoption behavior. Second, the effects of government support are often difficult to sustain due to the lack of effective monitoring of the quality of technology implementation. As the case of Huating City shows, although the government's material assistance has improved basic production conditions, whether farmers can strictly follow the technical specifications depends more on continuous and specific field guidance (Ruzzante et al., 2021) - which is precisely where the macro-level government support is difficult to reach. This is precisely the micro level where government support at the macro level is difficult to reach.

The empirical results show that government support does not significantly moderate the relationship between information coordination and quality improvement. This is mainly due to the fact that the effectiveness of information coordination depends largely on the intrinsic motivation of the participating entities. For example, in the case of the "Traditional Chinese

Medicine Safe Access" platform participated by Shanghai Municipal Herbal Medicine Co., the core motivation was the companies' own quality control needs and the constraints of the market reputation mechanism (Stranieri et al., 2021). For farmers, the fundamental reason for coordination through information entry is that it is directly related to the purchase price and marketability of TCMM. If information coordination is viewed as an administrative task rather than a means of proving quality in their favor, its effectiveness will be greatly diminished (Annosi et al., 2021).

5.6.3.4 Boundary conditions for the effectiveness of government support

Summarizing the results of the tests of the moderating effects described above, two key conditions that determine the effectiveness of government support can be identified. The first depends on the type of mechanism being supported (Sheng et al., 2011). For those mechanisms that involve long-term contracts and cross-subject coordination (for example, decision-making coordination), government support can play a positive role. However, for mechanisms that are highly dependent on spontaneous interactions and intrinsic willingness of both parties (for example, technology sharing, information coordination), the role of external interventions is very limited and may even have a negative impact. The second depends on the design of the intervention approach. When the government positions its role in providing institutional safeguards and professional services (for example, GAP compliance checks), it is easier to form synergies with market mechanisms. On the contrary, if the government forcefully intervenes in the spontaneous coordination of market players by rigid means, it is very easy to destroy the original foundation of trust and the quality of interaction (K. Z. Zhou & Poppo, 2010).

The four-wheel-drive governance mechanism implemented in Huating City provides important empirical evidence for the findings of this study. The city strictly defines government functions at the level of external resource provision and systemic risk sharing, mainly through economic and institutional tools such as material subsidies, awards in lieu of subsidies, industrial insurance, and loan subsidies (Ye et al., 2020), and avoids directly intervening in micro-coordination between firms and farmers that involves specific technical details. This logic of governance, which focuses on institutional empowerment rather than functional substitution, is highly consistent with the boundary conditions for the effectiveness of government support identified in this study (Lazzarini, 2015).

It should be noted, of course, that this study measures government support in a general way, failing to distinguish between types of subsidies, modes of support, and implementation agents. Different types of government support - financial subsidies versus technical services, direct

intervention versus indirect empowerment, and short-term programs versus long-term systems - may have different moderating effects. This is a limitation of this study and a direction that future research could deepen.

Chapter 6: Conclusions and Recommendations

6.1 Main research conclusions and recommendations

6.1.1 Main research conclusions

This study develops a theoretical model within the TOE framework, utilizing incomplete contract theory, transaction cost theory, agricultural technology diffusion theory, and farmer behavior theory. In this model, government support functions as a moderating variable, whereas technology adoption, technology sharing, information coordination, and collaborative decision-making serve as antecedents that impact the enhancement of quality in TCMM within the "company + farmer" framework. Our primary objective is to explore how the "company + farmer" model for cultivating TCMM can address the issue of raw material quality in TCMM. This study is the first to investigate the influencing factors of the quality of TCMM cultivation from the perspective of business models.

An initial examination of questionnaire data gathered from TCMM cultivation companies and farmers in diverse provinces of China revealed that farmers engaged in TCMM cultivation encounter difficulties, including limited planting experience, a significant population of small-scale farmers, and insufficient labor contributions. Furthermore, in our survey sample, the best places to grow TCMM are areas with a lot of natural resources, like mountains, hilly areas, plateaus, and canyons. The top ten categories of TCMM with the largest planting areas are Huangjing (Solomon's Seal), Maidong (Ophiopogon Root), Jinyinhua (Honeysuckle Flower), Touhualiao (Polygonum capitatum), Juhua (Chrysanthemum), Chuanxiong (Sichuan Lovage Root), Baiji (Bletilla Rhizome), Baishao (White Peony Root), Danshen (Salvia Root), and Baizhi (Angelica Root). About 41.46% of farmers join rural cooperatives to improve their bargaining power. More than half of the farmers have commercial insurance, which shows that they are aware of risk transfer from a social resource point of view. In terms of social relations, about 39.24% of rural households have at least one family member who is a village cadre or works for the government or a public institution.

We used PLS-SEM analysis on 539 valid questionnaires and checked and tested the theoretical model. This led us to the following main conclusions:

(1) Farmer technology adoption has positive impact on the quality of TCMM under the "company + farmer" model

Our research results show that there is a positive link between the use of technology and the quality of TCMM (H1). This is in line with earlier research that says that farmers' use of new technologies is a key factor in improving the quality of agricultural products (Rogers, 2003). Our results validate agricultural technology diffusion theory. Furthermore, previous research has pointed out that the technology used in the cultivation of Anoectochilus roxburghii (Burkill) can enhance the growth of medicinal plants (H. Liu et al., 2021). From a business model perspective, our study verifies that the "company + farmer" model for cultivating TCMM can clarify, through contractual relationships, the company's obligation to provide farmers with advanced cultivation techniques and regular training, thereby enhancing farmers' trust in the company's technical support. In other words, the contractual relationship between the company and farmers reduces farmers' perceived risk of uncertainty in technology adoption and increases their perceived usefulness of the technology shared by the company. Consequently, farmers are more willing to adopt the TCMM cultivation techniques shared by the company, thereby promoting the improvement of the quality of TCMM.

(2) Positive impact of company technology sharing on the quality of TCMM under the "company + farmer" model

Sharing technology is very important for improving the performance of organizations in supply chains (Ersoy et al., 2022). The "company + farmer" model for growing TCMM puts companies and farmers in important places in the supply chain. We can approximately consider them as a whole. Our research findings confirm that technological sharing between companies and farmers can play a role in improving the quality of TCMM. This means that for companies, in order to enhance performance and market competitiveness, they are motivated to provide farmers with technical guidance to improve the cultivation quality of medicinal materials. Meanwhile, farmers can more conveniently access advanced technologies, thereby improving the cultivation process and the final product quality of medicinal materials.

(3) Under the "company + farmer" mode, supply chain information coordination exerts a positive impact on the TCMM quality

Information sharing in the supply chain is of tremendous value (H. L. Lee et al., 2000), especially for peasant households at an information disadvantage. According to previous studies, a significant difference in information status lies between companies and peasant households, and peasant households are at a disadvantage in terms of acquisition of market information (Ruml & Qaim, 2021). According to findings of this study, under the "company + farmer" mode, supply chain information coordination is capable of relieving the information asymmetry between companies and peasant households. Information coordination between

companies and peasant households is more able to allow the companies to monitor the planting process of the peasant households, and to promptly give feedback and solve such problems encountered during planting of TCMM as plant diseases and insect pests, improper fertilization. Finally, this promotes the improvement in the TCMM quality. Our findings also work in concert with the previous studies, that is, improved information transparency provides an effective solution to product quality and safety problems (H. Feng et al., 2020).

(4) Under the "company + farmer" mode, supply chain decision-making synergy exerts a positive impact on the TCMM quality.

Successful synergic decision-making among supply chain partners can make it more possible for future coordination, and it is also conducive to building a long-term partnership (Ramanathan & Gunasekaran, 2014). Our study records the positive correlation between the supply chain decision-making synergy and the TCMM quality. This is in agreement with previous studies, that is, high-level coordination is capable of cutting the post-harvest crop losses (Despoudi et al., 2018). In addition, our findings also imply that, for peasant households, engagement in making decisions regarding planting orders and harvesting strengthens their sense of fairness about such decisions and their willingness to implement such decisions. Decision-making synergy between companies and peasant households fosters the enhanced mutual trust and the improved sense of fairness and willingness. Finally, this improves the TCMM quality.

(5) Under the "company + farmer" mode, the regulating role of government support demonstrates complexity.

According to findings of previous studies, multiple government support may have confusion effect (J. Y. Chen et al., 2019). This view is verified by our study. According to our findings, government support enables the up-regulation of the positive correlation between the supply chain decision-making synergy and the TCMM quality. However, the regulating effect of government support on the positive correlation between technology adoption & information synergy and the TCMM quality is statistically insignificant. Moreover, according to our findings, government support even negatively regulates the positive correlation between technology sharing and the TCMM quality, which suggests government support does not always play a positive role and its effectiveness is highly dependent on the specific links to which it applies.

Overall, under the "company + farmer" model for cultivating TCMM, technology adoption, technology sharing, information coordination, and decision-making coordination all have significant positive direct impacts on improving the quality of TCMM. This validates that the

model is an effective industrial organizational model for enhancing the quality of raw materials for TCMM. That is, farmers can achieve improved quality of the TCMM they cultivate by learning cultivation techniques shared by the company, understanding market-related information, and participating in the cultivation and related decision-making processes of TCMM.

6.1.2 Managerial implications and suggestions

We have found that the “company + farmer” model works well because it combines the strengths of both companies and farmers. We did this by carefully looking at survey data and doing a lot of research. This business model for TCMM is very important for the industry to grow in a high-quality way. The “company + farmer” cultivation model also sets a strong foundation for the TCMM industry to grow in a standardized and large way.

But we also need to be aware that when it comes to government support for improving the quality of TCMM under this business model, the way it works and the policies it uses are like walking a tightrope, so we need to be more careful and thorough. Too much or too little government support, as well as unfair policy arrangements, can make it harder to improve the quality of TCMM, which can hurt the long-term growth of the whole TCMM industry.

Based on the above rigorous research conclusions, to effectively promote the high - quality development of the “company + farmer” TCMM business model, precisely meet the urgent commercial demand of the market for high - quality TCMM and thus contribute to the vigorous development of the TCM cause, this study puts forward the following series of targeted and operable suggestions:

(1) Encourage farmers to participate in the “company + farmer” business model for TCMM cultivation

In various business models of contract farming, farmers are at a disadvantageous position compared to companies. They are not only at a disadvantage in terms of scale, capital, information, technology, and knowledge. Especially in China, small-scale peasant economy and individual peasant households dominate. The cultivation of TCMM differs from that of other fruits and vegetables in that it has stricter acceptance standards.

For example, the 2025 edition of the Chinese Pharmacopoeia imposes stricter requirements on the quality control of TCMM. In terms of origin and identification, it clarifies the identification characteristics of certain easily confused medicinal materials and introduces DNA barcoding technology for molecular identification. Regarding content determination, it

adds or revises standards for the content of active ingredients. For instance, the total requirement for ginsenosides Rg1, Re, and Rb1 in ginseng is increased from 0.25% in the 2020 edition to 0.30%. In terms of impurity inspection, it sets stricter requirements for safety indicators such as heavy metals, pesticide residues, and mycotoxins. For example, it adds limits for lead, cadmium, arsenic, mercury, and copper in Corydalis yanhusuo (lead ≤ 5 mg/kg, cadmium ≤ 1 mg/kg). To control pesticide use, the number of banned pesticides has increased from 33 to 47, with the total number of banned ingredients rising from 55 to 72. Fourteen new highly toxic pesticides, such as metsulfuron-methyl and methamidophos, have been added. In addition, the 2025 edition of the Pharmacopoeia also introduces new requirements for mycotoxins and plant growth regulators.

Thus, it is difficult for ordinary farmers to grow medicinal herbs that meet market demands without having received specialized training in cultivation techniques. These include effective constituent content, pesticide residues, heavy metal content, and testing methods. We also discovered that authentic TCM institutions do not directly procure TCMM from individual farmers involved in its cultivation. One reason is that these farmers can only provide a small amount of medicinal materials. On the other hand, their lack of planting knowledge and techniques results in the TCMM they produce rarely meeting the market's required standards.

Therefore, based on our research findings, we encourage more farmers to participate in the "company + farmer" business model for TCMM cultivation. By signing cultivation contracts with companies, farmers can learn good cultivation techniques for TCMM from the companies and improve their own cultivation levels. Moreover, participating in the "company + farmer" model can also help farmers break through existing market entry barriers and participate in a larger market for buying and selling TCMM. The signing of contracts can also, to a certain extent, reduce their exposure to market risks. Additionally, during the coordination with companies, farmers can implicitly learn a lot of knowledge about TCMM cultivation.

Our analysis of the basic information in the questionnaires also reveals that less than half of the farmers have participated in rural cooperatives. More than 60.44% of the farmers have taken out commercial insurance. Given that farmers are at a disadvantageous position and have insufficient bargaining power in the "company + farmer" business model for TCMM cultivation, and that farmers also face the risk of being exploited by companies in contract farming (Martin & Mwaseba, 2015), we suggest that farmers should participate more in rural cooperatives. By relying on rural cooperatives to sign contracts with companies, they can increase their voice in negotiations. Furthermore, we also recommend that farmers use more commercial insurance to

transfer potential risks that may arise from the "company + farmer" business model for TCMM cultivation.

(2) Appropriately "delegate power" to promote the healthy development of the "company + farmer" business model for TCMM cultivation

Supply chain organizational coordination plays a crucial role in improving organizational performance (Chu et al., 2025). From the perspective of supply chain coordination, our research finds that supply chain information coordination and decision-making coordination can promote the improvement of the quality of TCMM. For contract farming, farmers' willingness to participate is closely related to the contract terms (Barrett et al., 2012). Unfavorable contract requirements and perceptions of unfairness in contract farming are the main reasons why farmers refuse to participate (Vamuloh et al., 2020). To promote the healthy development of the TCMM industry chain and achieve a win-win situation between companies and farmers in the "company + farmer" TCMM planting business model, we suggest that companies appropriately delegate authority. Specifically, we propose the following recommendations:

Firstly, for companies, they can upgrade their management of farmers from simple order procurement to deep coordination. They should actively establish long-term technical training and sharing mechanisms, transparent and mutually trusting information exchange mechanisms, and democratic decision-making coordination mechanisms. By treating farmers as partners in high-quality development, they can jointly improve the quality of TCMM.

Secondly, our research indicates that government support shows significant differences in regulating our direct effects. From our research results, government support plays a very limited role, and even has a negative impact, in the "company + farmer" business model for TCMM cultivation. To address this situation, we suggest that companies should actively connect with and integrate policy resources. Companies should closely monitor and actively apply for various support policies provided by the government, and make good use of the public platforms built by the government to reduce coordination costs, transforming policy dividends into competitive advantages for their collaborative development with farmers.

Finally, companies should view the government's role dialectically and maintain collaborative autonomy. Companies should recognize the dual nature of government support. While actively seeking government resources, they should also have the courage to safeguard their autonomy and flexibility in areas such as technology sharing and information coordination with farmers, avoiding damaging the most efficient market-oriented coordination mechanism due to excessive reliance on or catering to government projects.

(3) The government implements precise empowerment to optimize policy support

Although in our research, government support only plays a positive moderating role in the path of supply chain decision-making coordination and the improvement of the quality of TCMM, it is undeniable that as an important external factor, government support plays a crucial role in various aspects such as social entrepreneurship (Stephan et al., 2015), innovation output (Kwan & Chiu, 2015), and promoting the development of science and technology (Shu et al., 2015). In actual production, to promote the development of the TCMM cultivation industry, the Chinese government has provided a series of supports.

We believe that government support plays a significant role in agriculture, especially in the field of TCMM. However, government support is a complex issue. Based on our research results, we propose the following three suggestions for government departments:

Firstly, adhere to and optimize macro support. The government should continue to provide support in terms of financial subsidies, the formulation of national standards and origin specifications, and the construction of public infrastructure (such as traceability platforms and big data centers) to lay a solid material foundation for the quality upgrade of the "company + farmer" model.

Secondly, implement precise empowerment and focus on decision-making coordination. We find that in the "company + farmer" business model for TCMM cultivation, government policies should focus more on empowering "decision-making coordination." For example, by supporting the establishment of industrial alliances, organizing production-marketing docking meetings, and providing third-party decision-making consulting services, the government can promote the formation of a joint decision-making mechanism between companies and farmers that shares risks and benefits, rather than directly interfering in enterprise operations.

Thirdly, transform roles and stimulate endogenous motivation. When encouraging "technology sharing," the government should pay attention to transforming from a "leader" and "commander" to a "service provider" and "guardian." It should avoid administrative-order-style and formalistic interventions as much as possible. The focus of government support should be on cultivating and stimulating a spontaneous, efficient, and down-to-earth technology exchange ecosystem between companies and farmers through measures such as building market-oriented technology trading platforms, establishing "industry-university-research" coordination incentive funds, and strictly protecting intellectual property rights, so that market mechanisms and the vitality of micro-subjects become the main driving forces for technology sharing.

6.2 Contributions and research limitations

6.2.1 Theoretical and practical contributions

On the basis of a systematic review of relevant literature on agricultural technology diffusion and supply chain coordination, we proposed and validated a theoretical model regarding how the "company + farmer" business model for TCMM cultivation enhances the quality of TCMM, thereby enriching relevant research. The main theoretical and practical contributions of this study are as follows:

(1) Theoretical contributions

Firstly, this study applies the theories of agricultural technology diffusion and supply chain coordination to the context of the "company + farmer" business model for the cultivation of TCMM with Chinese characteristics. It systematically conducts empirical tests on the mechanism through which the TOE integrated framework enhances the quality of TCMM, thereby enriching theoretical research in the field of agricultural industrialization. By constructing a rigorous theoretical model and carrying out extensive field research, this study delves deeply into how technological elements, with the aid of organizational structures, can promote the optimization and upgrading of the quality of TCMM under specific environmental contexts. This enriches theoretical research in the field of TCMM industrialization and provides a new perspective and empirical support for the refinement of the theoretical system in this field.

Secondly, focusing on the promoting effect of the "company + farmer" business model for TCMM cultivation on farmers' field cultivation practices, this research has, to a certain extent, enriched the research on the consequences of the "company + farmer" industrial model for TCMM. Based on collecting farmers' cultivation data and conducting interviews, we conducted a detailed analysis of farmers' specific behaviors in adopting cultivation techniques, optimizing supply chain coordination, and improving the quality of TCMM under this business model. Our study reveals the positive impact of business model innovation on farmers' cultivation practices. This provides practical reference and theoretical support for further optimizing the "company + farmer" business model for TCMM.

In addition, we reveal the double-edged effect of government support. On one hand, government support strengthens the positive impact of decision-making coordination on the quality improvement of TCMM. However, government support also weakens the positive impact of technology sharing on the quality improvement of TCMM. Through micro-level data analysis, the study shows that some government support measures face issues such as poor

information transmission and low acceptance among farmers during the technology promotion process. This results in unsatisfactory effects of technology information regulation.

This finding reveals that the effectiveness of government support highly depends on the specific governance dimensions being regulated. The traditional perspective of viewing government intervention in the field of TCMM cultivation in a generalized manner has limitations. We challenge the conventional belief that government support inevitably promotes the high-quality development of the TCMM industry. This study provides new theoretical boundaries and contextual conditions for understanding the role of the government in the multi-party coordination among the government, companies, and farmers.

(2) Practical contributions

The conclusion of this study provides the corporate champions in the TCMM sector with a management practice path for optimization of the "company + farmer" mode and high-quality development. As an important way for peasant households to break down the technology and market barriers, the "company + farmer" mode can provide the peasant households with technical training, stable orders and a risk cushioning mechanism, so as to give an effective boost to sustainable development of peasant households.

In addition, the empirical results of this study provide the government with an explicit empirical basis and a direction when the government develops accurate and efficient supportive policies for the TCMM sector. In this way, it avoids the waste of policy resources, mitigates the potential negative effect, and ensures that policy intervention has effectively taken effect. Finally, relying on the improved quality of raw materials of TCMM, this study, from the perspective of management science, presents the solution for guaranteeing the effectiveness of TCMM and satisfying the health needs of the public. This highlights the practical importance and profound influence of this study in driving the overall development of the TCMM sector.

6.2.2 Limitations of this study and future prospects

This study has explored and verified the established theoretical model in a systematic and in-depth manner, and reveals the possible mechanism for the "company + farmer" model to improve the TCMM quality. However, due to limited research conditions, difficult access to questionnaire data, narrow scope of this study and other constraints, our study exhibits some limitations. For the purpose of driving the study efforts in this field to go further, future studies may be improved on the basis of the following several key dimensions:

(1) Broadening the types of business models studied

This study focuses on the mechanism of the "company + farmer" mode, a classic business model, in improving the TCMM quality under the circumstance of planting of TCMM. From the perspective of academic research, the "company + farmer" mode is not an isolated and closed concept. Instead, it represents one of a variety of differentiated sub-modes gradually derived from the long-term development practice of the TCMM sector in China.

Different business models show considerable differences in organizational structure design, rules for profit distribution, risk sharing mechanism, resource integration and allocation capability and other aspects. These differences exert further impact on the management throughout the process from planting to harvesting of TCMM, and finally produce varying degrees of shadows on the TCMM quality. For instance, the biggest feature of the "company + base + farmers" mode lies in the construction of standardized planting bases. This mode can control the planting environment in an accurate way, standardize the planting techniques and enable strict management of the inputs, so as to provide effective guarantees for the stability and consistency of TCMM (Ou et al., 2025). The "cooperative + farmers" mode has unique superiority in motivating peasant households to produce, promoting appropriate planting techniques. It pays more attention to information sharing, exchange of skills and coordination among peasant households. Therefore, this mode is better in driving supply chain coordination.

Given the limitations of this study regarding the types of medicinal plant cultivation models, future research could further explore subcategories of the "company + farmer" model. For example, future studies could systematically evaluate the advantages and disadvantages of models such as "company + base + farmer," "cooperative + farmer," and "company + cooperative + farmer," as well as the multiple impacts of these models on the quality of medicinal herbs. Additionally, future research could construct a multidimensional analysis framework that includes organizational structure, profit distribution, risk-sharing mechanisms, and resource integration. By combining quantitative and qualitative research methods, such studies can provide a comprehensive analysis of the ways to improve the quality of TCMM, differences in effectiveness, and related contextual factors under different business models.

(2) Expanding the collection of research samples

China has a total of 34 provincial-level administrative regions, and almost all provinces cultivate TCMM. However, in terms of the scale of cultivation, varieties, and the industrial status of medicinal plants, there are significant differences among provinces. We have made efforts to collect data from respondents across various provinces in China.

However, our survey data primarily come from 21 provinces, including Sichuan, Jiangsu, Guizhou, Anhui, and Yunnan. From a regional perspective, these provinces do not fully cover China's renowned authentic TCMM production areas.

We recommend that future research should further expand the geographical scope of surveys to verify the applicability of the conclusions of this study. For instance, future research could select medicinal material cultivation areas covering different climatic zones, soil types, and levels of economic development as study subjects. Adopting such an approach can enhance the generalizability and reliability of the research findings, thereby providing more targeted and practical theoretical support for the scientific formulation of policies in the TCMM industry.

(3) Broadening data types

This study evolves relying on cross-section data and its advantage lies in its ability to capture the relation between different individual variables in an accurate manner and at specific time nodes, thus establishing a basis for exploration of the relations of industry factors. But there are significant limitations to cross-section data, which influences the rigor of research conclusions. In terms of individual heterogeneity, there are considerable differences in planting experience and management level among different peasant households in the TCMM sector. Experienced peasant households are good at selecting varieties and planting time, and peasant households with high management skills are adept at extermination of diseases and insect pests. These differences help improve the quality. However, it is difficult to separate and quantify the cross-section data in an accurate way. Analysis of the impact of government support policies on the quality is susceptible to individual differences, resulting in reduced accuracy of the conclusions.

Specifically, dynamic changes such as policy adjustments, market demand fluctuations, and technological advancements have profound impacts on the industry. For instance, government subsidy policies can alleviate the financing constraints faced by companies and farmers during production investment. Changes in the market demand for TCMM affect the quantity of medicinal materials planted by farmers. Technological development can improve productivity and promote the updating of previously outdated cultivation machinery for medicinal materials. In addition, the methods for testing the quality of medicinal materials are continuously updated with technological advances, which places higher demands on the measurement of medicinal material quality.

When studying the relationship between government support and quality improvement, it is easily affected by issues of reverse causality or omitted variable endogeneity. As an instance, improvements in quality might lead to the implementation of government policy, or factors in

the economy that are not visible could affect both policy and quality at the same time, making it hard to figure out how they are related. To more rigorously test causal relationships and reveal dynamic mechanisms, future research can diversify data types in two ways: First, promote longitudinal case studies. Select typical enterprises or farmers with different scales, regions, and business models as cases. Enterprises can be screened based on factors such as output value and market share, while for farmers, factors like cultivated area and years of cultivation can be considered. Second, construct panel data models. Collect multi - year, multi - entity tracking data to build a panel data set. Use fixed - effect and random - effect models to control for individual characteristics and macro - time trends, and clearly identify the causal effects of government support, collaborative behaviors, and the quality of TCMM. By diversifying data types and improving research methods, it is expected to make up for the research deficiencies, enhance the rigor and reliability of the conclusions, and provide strong support for the sustainable development of the TCMM industry.

(4) In-depth study of the regulating effect

In this study, we discovered distinct empirical findings concerning the moderating influence of government support. The research specifically demonstrates that government support enhances the impact of decision-making coordination on the enhancement of the quality of TCMM. But government support has a bad effect on technology sharing, and it does not have a big effect on technology adoption or information sharing.

It is important to point out that this study is a relatively rough measure of government support. Each type of policy tool may exert a unique impact on the relation among diverse variables in the TCMM sector. Actually, government support involves a variety of dimensions. A more sophisticated method shall be used to gain a full understanding of the role of government support.

Looking ahead, follow-up studies shall involve more sophisticated regulating variables. Types of policy tools like subsidies, regulation and services offer a very promising direction for exploration. Furthermore, the manner in which the policies are implemented is another important factor. Whether a policy is implemented according to top-down directives or by means of bottom-up engagement is of obvious significance to results. If future studies use these variables as regulating variables, it is possible to go deeper into the boundary conditions and underlying mechanisms of the observed crowding out effect of government support. This can not only allow for a stronger theoretical dimension to studies, but also offer more practical insights to decision makers in the TCMM industry.

(5) Introducing more diversified variables

We recognize that, the current study model is relatively simple, and it merely goes into the direct effects of technology adoption, technology sharing, information coordination and decision-making synergy on TCMM and the regulating effect of government support amid these four effects. Future studies can involve more diversified variables like peasant household characteristics, environmental uncertainty, corporate culture, peasant household trust and end consumer feedback, so as to make the models better and reveal the motivational mechanism for quality improvement of TCMM in a more comprehensive manner.

(6) Limitations in testing sample heterogeneity

The sample of this study comprises two distinct groups: TCMM companies and farmers. Theoretically, this provided an opportunity to examine the heterogeneity of the cross-sectional data. We attempted to employ multi-group analysis to compare path coefficients between the two groups, aiming to explore the stability of the core relationships across different subjects. However, during the operational phase, we encountered significant disparities in the background characteristics of the two groups. For instance, the company questionnaire included variables such as firm age, ownership structure, scale, and revenue, whereas the farmer questionnaire included age, education level, planting experience, and planting area. Consequently, we were unable to construct unified variables to conduct a rigorous multi-group comparison.

Furthermore, when attempting to run the multi-group analysis, we encountered computational issues involving a singular matrix. Diagnostics suggested this likely stemmed from insufficient variance in certain items for specific groups after segmentation, or limitations in sample size distribution. Therefore, this study was unable to perform a group-based comparison. The core conclusions are derived from a full-sample analysis, and we cannot statistically verify whether significant differences exist between the company and farmer groups. Future research could pre-establish unified grouping variables during the questionnaire design phase or increase the sample size to conduct independent analyses for each group. Such approaches would allow for a deeper exploration of sample heterogeneity and provide more precise evidence regarding the cross-group applicability of the findings.

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Annex: Survey Questionnaire

Part I: Basic Information

Pannel A: Farmer's socio-demographic characteristics

Item	Category
Gender	Male
	Female
Age	18-24 years
	25-34 years
	35-44 years
	45-54 years
	55 years and above
Education Level	Below high school
	High school/Secondary specialist
	Associate degree
	Bachelor's degree
	Master's degree and above
Experience in Cultivating TCMM	0-5 years
	6-10 years
	11-20 years
	21 years and above
Scale of TCMM Cultivation	0-3 mu
	4-10 mu
	11-30 mu
	31-100 mu
	101 mu and above
Topography for TCMM Cultivation	Mountains, Hills/Mountains, Plateau, Valleys
	Plain, Basin, Alluvial Fan
	Coastal Plain, Coastal Hills, Tidal Flats, Island
	Desert, Gobi (Gravel Desert), Grassland, Loess Hills
Membership in Agricultural Cooperative	Yes
	No
Available Household Labor Force	1 person
	2 persons
	3 persons
	4 persons
	5 persons and above
Participation in Agricultural Insurance	Yes
	No
Access to Formal/Informal Credit	Yes
	No
Whether any household member holds a position as a village cadre or is employed in a government/public institution	Yes
	No

Pannel B: Company's socio-demographic characteristics

Item	Category
Firm Age	0-5 years
	6-10 years
	11-20 years
	21 years and above
Ownership Type	State-owned
	Private
	Foreign-funded
	Collectively-owned
	Other
Total Assets	0-1 million CNY
	2-10 million CNY
	11-100 million CNY
	101 million CNY and above
Revenue	0-3 million CNY
	4-20 million CNY
	21-100 million CNY
	101 million CNY and above
Number of Employees	0-50 employees
	51-100 employees
	101-200 employees
	201 employees and above
Number of Farmers under Contract	0-50 farmers
	51-100 farmers
	101-200 farmers
	201 farmers and above
Position	Senior management
	Department head
	Middle management
	Technical professional
	Frontline operations staff

Part II: Questionnaire Items

Construct	Item	Source
Technology Adoption	TA1: The Chinese medicinal material cultivation technology promoted by the company enables farmers to perform farming operations with less labor intensity. TA2: The Chinese medicinal material cultivation technology promoted by the company enables farmers to achieve higher planting efficiency. TA3: The Chinese medicinal material cultivation technology promoted by the company enables farmers to improve the quality of their medicinal material products. TA4: The Chinese medicinal material cultivation technology promoted by the company is relatively easy for farmers to master.	Davis (1989)
Technology Sharing	TS1: The company's sharing of Chinese medicinal material cultivation technology has strengthened its connection with farmers. TS2: The company's sharing of Chinese medicinal material cultivation technology has increased the likelihood of future coordination with high-quality farmers. TS3: The company's sharing of cultivation technology has helped farmers solve problems. TS4: The company maintains close ties with farmers. TS5: The sharing of technology between the company and farmers is highly valuable to both parties. TS6: The company intends to share work experience or professional knowledge with farmers more frequently in the future.	Bock et al. (2005)
Information coordination	IC1: The company regularly shares information on high-quality medicinal material varieties with farmers. IC2: Farmers regularly share their planting plans with the company. IC3: The company regularly shares market demand forecasts for medicinal materials with farmers. IC4: The company regularly shares current and historical market prices of medicinal materials with farmers. IC5: The company regularly shares its medicinal material inventory information with farmers. IC6: The company regularly shares test results of the cultivated medicinal materials with farmers.	Flynn et al. (2010); Lawson et al. (2009)
Decision-making coordination	DMC1: The company considers the opinions of farmers when establishing quality standards for medicinal materials. DMC2: The company considers the opinions of farmers when setting order prices for medicinal materials. DMC3: The company considers the opinions of farmers when determining order quantities for medicinal materials. DMC4: The company considers the opinions of farmers when setting delivery schedules for medicinal materials. DMC5: The company takes into account the opinions of farmers when establishing payment terms for medicinal materials.	Soosay et al. (2008); Cao & Zhang (2011)
Government support	GS1: You are well-versed in the government-provided subsidy policies for cultivation techniques.	Li & Atuahene-

	GS2: Government support covers the primary costs of investing in new technologies. GS3: Agricultural technicians' on-site guidance has addressed the challenges in technical application. GS4: Government regulation has prompted the adoption of more quality-oriented technologies and management practices in medicinal material production.	Gima (2001); Yang et al. (2019)
Quality of TCM	QE1: The active ingredient content of the produced medicinal materials complies with the relevant standards of the Chinese Pharmacopoeia. QE2: The pesticide residue test results for medicinal materials produced in the past three years have all complied with national and industry standards. QE3: The heavy metal test results for medicinal materials produced in the past three years have all complied with the standards. QE4: The produced medicinal materials exhibit satisfactory organoleptic characteristics (e.g., color, odor, shape, texture).	2025 Edition of the Chinese Pharmacopoeia