CHINA AND GLOBAL FOOD POLICY REPORT

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REFORMING AGRICULTURAL SUPPORT POLICY FOR TRANSFORMING AGRIFOOD SYSTEMS

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Contents

Foreword I ······ v
Xiwen Chen

Foreword II ······ vii
Qixin Sun

Executive Summary ······ ix
Shenggen Fan, Kevin Z. Chen, Jing Zhu, and Wei Si

Acknowledgments ······ xiii

Chapter 1 **Evolution of Agricultural Support Policies** ······ 2
Yumei Zhang, Ting Meng, Xiangmin Lan, Shenggen Fan, Kevin Z.Chen,and Wei Si

Chapter 2 **Reforming Support Policies to Improve Chinese Nutrition and Diet** ······ 14
Qiran Zhao, Yumei Zhang, Shenggen Fan, Kevin Z. Chen, Yi Cui, and Ying Zhang

Chapter 3 **Repositioning Agricultural Support Policies for Achieving China's 2060 Carbon Neutrality goal** ······ 38
Xiaolong Feng, Yumei Zhang, Zongyi Wu, Shenggen Fan, and Kevin Z. Chen

Chapter 4 **Repurposing Agricultural Support Policies for Improved Nutritional Outcomes and Green and Low-Carbon Development** ······ 56
Yumei Zhang, Shenggen Fan, Kevin Z. Chen, Wei Si, Xiangmin Lan, and Jingjing Wang

Chapter 5 **China's Fiscal Expenditure on Agriculture: Impact on the Urban–Rural Income Gap** ······ 72
Rui Mao, Maoqi Ruan, Xinjie Shi, Weiqi Sun, and Kevin Z. Chen

Chapter 6 **Reforming China's Domestic Agricultural Support under the International Trade Framework** ······ 96
Xuejun Wang, Liang Xu, Wenrui Zhang, Zhengkai Fu,and Jing Zhu

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CHINA AND GLOBAL FOOD POLICY REPORT 2022

REFORMING AGRICULTURAL SUPPORT POLICY FOR TRANSFORMING AGRIFOOD SYSTEMS

Foreword I

In 2021, China produced more than 680 million tons of grains and its per capita grain possession reached 483 kg. With nine percent of the world's arable land and six percent of the world's freshwater resources, China has successfully fed 18% of the world's population, thus, contributing to the global goals of hunger eradication and food security. However, due to improvements in people's living standards and the upgradation of the food consumption structure, the total food consumption and the total food supply in China reveals a gap, and certain foods are particularly undersupplied. At the National Committee of the Chinese People's Political Consultative Conference in March 2022, President Xi Jinping emphasized the need for a "Big Food Concept" to ensure the effective supply of meat, vegetables, fruits, aquatic products, and other types of food, while sustaining the supply of staple grains. To establish and apply this Big Food Concept, a shift in the focus of food security is required, that is, from ensuring the supply of staple grains to the adequate supply of diversified food products.

At present, China faces multiple challenges in food security. First, the agricultural production foundation remains weak, highlighted by the difficulties in protecting and improving the quality of arable land and innovation capacity of the seed industry. Second, the increase in food production has strained the country's resource carrying capacity, leading to significant environmental pollution by chemical fertilizers, pesticides, agricultural plastic films, and livestock and poultry manure. Third, domestic agricultural support policies are limited because they are subject to the ceiling of international prices, the WTO's "amber box," and other restrictions. Fourth, in addition to the natural, market, and other traditional risks, agriculture also contends with the risk of pandemics, regional conflicts, international market risks, and non-traditional risks in the ever-evolving world stage.

To address these challenges and achieve major national strategic goals, such as Rural Revitalization, Common Prosperity, "Double Carbon" Goals, Ecological Civilization, and Healthy China, China needs to urgently transform its agriculture, and agricultural support policies need to be adjusted and optimized accordingly. In this context, the 2022 China and Global Food Policy Report, with the theme of "Optimizing Agricultural Support Policies to Promote the Transformation of Agrifood Systems," is particularly timely and important.

Based on the data and models, the report focuses on the evolution of agricultural support policies in China and worldwide, and the impact of China's agricultural support policies on nutritional health, resources and environment, common prosperity, and international trade. The report features an interdisciplinary, multisectoral, and close integration of international perspectives with Chinese practices. It proposes to reposition the targets of agricultural support policies, promote balanced diets and nutrition improvement with the Big Food Concept, support the transformation of subsidy policies and scientific and technological inputs toward green, low-carbon and sustainable development, optimize the structure and regional distribution of central financial support for agriculture to promote urban-rural integration, and promote the continued shift of agricultural support policies from the "amber box" to the "green box." These policy suggestions provide important references for policymakers, researchers, and industry practitioners. Furthermore, the report will help to direct Chinese agriculture toward a nutritious and healthy, green and low-carbon, high-quality and efficient, and resilient and inclusive direction, and ensure food security not only in China, but also worldwide.

Xiwen Chen
Chairman of Agriculture and Rural Affairs Committee of National People's Congress
Chairman of Academic Committee of Academy of Global Food Economics and Policy

Foreword II

Over the past few decades, China's agrifood systems have made remarkable achievements in food security, national nutrition, and farmers' income. However, these systems continue to face many challenges, such as unreasonable dietary structure, diminishing resources and environmental constraints, aggravated climate change impacts, complex international situations, and insufficient development capacity of small farmers. The agricultural support policy is an important way to promote the transformation of the agrifood systems, which has promoted food production, agricultural development, and farmers' income. However, the agricultural support policy in nutrition, health, and green and low-carbon initiatives is relatively insufficient, it is difficult to further the national development goals to the next stage.

The Academy of Global Food Economics and Policy (AGFEP) of China Agricultural University (CAU), led by Professor Shenggen Fan, has initiated the "2022 China and Global Food Policy Report" (bilingual: Chinese and English) in conjunction with domestic and foreign institutions to focus on reforming China's agricultural support policies, based on multidisciplinary data and empirical research and analyze the agricultural support policies status and its impact on nutrition and health, resource and environment, common prosperity and international trade, to help transform agrifood systems. The 2022 report presents practical cases from China with a broad international perspective. The 2022 report follows their invaluable "2021 China and Global Food Policy Report." The 2021 report focuses on China's agrifood systems and their path of transformation in the post-pandemic era. The published report attracted widespread attention and led to discussion among domestic and foreign policymakers and researchers as it highlighted Chinese cases and solutions applicable for the transformation of global agrifood systems in the post-pandemic era. Additionally, it represented the Chinese viewpoint at the 2021 United Nations Food System Summit. Furthermore, I believe that the 2022 report can provide an important reference for policymakers and researchers.

The 2022 report concludes that reforming agricultural support policies to promote agricultural, scientific, and technological innovations is not only a powerful measure to ensure food security but also key to achieving national nutrition, health, and green and low-carbon development of agrifood systems. The CAU's mission and responsibility are to promote agricultural, scientific, and technological innovations and serve the major needs of national science and technology in agriculture. In this respect, it has had several outstanding achievements through its actions, contributing to China's high-quality agricultural development and rural modernization. For example, in 2021, the CAU launched "ten major actions for scientific and technological innovation in the agricultural seed industry," that focused on the needs of crops, livestock and poultry, horticulture, grassland, and other seed industries with independent innovation as the core. It delivered scientific and technological research and talent training to create a strategic scientific and technological force in the seed industry, and lead the innovation and development of agricultural science and technology to implement these strategies. In the future, guided by the major needs in national agricultural science and technology and the international academic frontier, CAU will continue to employ the advantages and characteristics of multi- and inter-disciplinary research to better serve the national diversified development goals of food security, national nutrition and health, green and low-carbon development, and common prosperity through innovation and talent training of agricultural science and technology.

Qixin Sun
President of China Agricultural University

Executive Summary

Remarkable achievements in global food security have been made in the past several decades. Food production has grown significantly and outpaced the population growth. Household food consumption has increased, and undernourishment has declined dramatically. However, due to multiple risks and threats such as climate change, COVID-19, environmental degradation, trade frictions, and regional conflicts, global food security and nutrition face unprecedented challenges. In fact, the number of hungry people in the world has been increasing since 2015, with more than 800 million people now suffering from hunger. After decades of development, China has ended hunger. In the new development stage, the Chinese government has proposed even higher development goals; these include Healthy China 2030, Rural Revitalization, Ecological Civilization, Common Prosperity and Carbon Neutrality.

Agriculture and food systems (agrifood systems) are the foundation for progress toward the goals of national nutrition, food security, ecological sustainability, common prosperity, and carbon neutrality. Agrifood systems encompass food and agricultural products from agriculture, forestry, animal husbandry, fishery, industry and service industries; it also includes all actors and their interconnected roles in the whole process of input, production, storage, transportation, processing, sales, consumption and disposal, as well as the broader economic, social and natural environment. Agrifood systems should ensure food security and nutrition in an environmentally sustainable manner; they should be resilient and inclusive and should also support the livelihoods of all people. China's agrifood systems, however, currently face many challenges. First, challenges in consumption, including unbalanced diets, the coexistence of overweight/obesity and micronutrient deficiency, and the rise in chronic diseases, have rapidly emerged. Second, there is increasing pressure on resources and growing environmental constraints on agricultural production, and climate change and extreme weather events have begun to significantly impact agrifood systems. Third, domestic and international markets are becoming more closely linked than ever, but complex international situations and emergencies have exacerbated trade risks. Fourth, smallholders have insufficient ability to connect with large markets and they lack empowerment and the capacity to cope with risks. China therefore urgently needs to transform its agrifood systems to become more nutritious and healthier, greener and lower carbon, and more efficient, resilient, and inclusive.

It is an opportune time to transform agrifood systems both globally and domestically. The 2021 United Nations Food Systems Summit, the 2021 United Nations Climate Change Conference (COP26), and the 15th Conference of the Parties to the United Nations Convention on Biological Diversity (COP15) all regard the transformation of agrifood systems to be essential. China’s No. 1 Central Document is the first document issued by the central government in the beginning of the year. In 2022, this document emphasized the promotion of green and high-quality agricultural development. At the “Two Sessions” of 2022 (the National People's Congress and the Chinese Political Consultative Conference), President Xi Jinping emphasized the need to establish the “Big Food” concept, which aims to improve people’s lives and livelihoods. While ensuring a steady supply of grain, it needs to also develop food resources and categories that guarantee an effective supply of various foods including meat, vegetables, fruits, and aquatic products, with the aim of achieving a balance of food supply and demand. Agricultural support policies are an important tool in this process; they play a critical role in enhancing food production, supporting agricultural development, increasing farm incomes, and reducing rural poverty. Current policy formulation and implementation focus mainly on the quantitative aspects of food security; their consideration of nutrition and health and of green and low-carbon goals is minimal. Repositioning agricultural support policies to facilitate the transformation of agrifood systems has therefore become a vital issue, in China as well as globally.

In this context, the 2022 China and Global Food Policy Report was jointly published by Academy of Global Food Economics and Policy (AGFEP) of China Agricultural University, China Academy of Rural Development (CARD) of Zhejiang University, Center for International Food and Agricultural Economics (CIFAE) of Nanjing Agricultural University, Institute of Agricultural Economics and Development (IAED) of Chinese Academy of Agricultural Sciences and International Food Policy Research Institute(IFPRI). The report explores how to reposition China's agricultural support policies in the new development era. It follows up on the 2021 China and Global Food Policy Report, which focused on the transformation pathways for Chinese agrifood systems. It highlights the evolution of agricultural support policies and analyzes their impact on nutrition and health, on resources and environment, on common prosperity, and on international trade. The report is written on the basis of cross-sectoral and multidisciplinary research, highlighting Chinese practices from a global perspective. It also aims to provide scientific and rigorous evidence for policymakers, researchers, and practitioners of agrifood systems.

Chapter 1 of the report investigates the evolution and impact of global and Chinese agricultural support policies. It summarizes the experience of China's agricultural support policy reform and analyzes the challenges being faced by China's agrifood systems. Chapter 2 is based on an analysis of changes in the dietary structure of China's urban and rural populations over the last 20 years. It explores how to increase the supply of nutritious and healthy food and how to improve the food purchasing power of rural low-income populations such that the national goal of dietary balance and nutritional health can be achieved. Chapter 3 systematically analyzes agricultural support policies and their impacts on the environment. It conducts simulation analyses and puts forward a policy optimization plan whose goal is to achieve the emissions reduction from agrifood systems while ensuring food security. Chapter 4 considers multiple development goals such as improved nutrition and health and green and low-carbon targets. It analyzes adjustments in agricultural subsidies and increased public investment in agriculture in terms of their impact on food security, economic benefits, the quality of citizens' diets, and carbon emissions. Chapter 5 summarizes the nature and development of China's financial support for agricultural development since the reform and opening up. It investigates the effect of financial support for agriculture on narrowing the per capita income gap between urban and rural population and the mechanism by which this has occurred. It also summarizes the innovative exploration and implementation of financial support for agriculture in Zhejiang Province. Chapter 6 analyzes the adjustment pressure faced by China's agricultural support policies under the current World Trade Organization (WTO) trade rules and reforms. It proposes a policy optimization plan that is based on reducing the "amber box" policies that distort agricultural production and trade and increasing the "green box" policies that have little distortion.

This report draws the following conclusions:

1. The intensity of China's agricultural support has increased significantly. Between 2018 and 2020, it accounted for 22 percent of the agricultural GDP, which is close to the world average of 23 percent. The country's agricultural support policies have effectively guaranteed food security and promoted the increase of farmers' incomes; in the meantime, these policies have also limited market distortion and reduced hunger and poverty. At present, however, policies have insufficient consideration for, and investment in, nutrition, health, natural resources, and environment; it is thus not possible to meet the current objectives of national nutrition and health and of green and high-quality development. It is therefore urgent that China's agricultural support policies be further optimized and adjusted.

2. China's populations are facing the challenges of poor dietary structure and unbalanced nutrition. The supply of nutritious and healthy food can be increased and population's ability to obtain such food can be improved by measures such as increasing subsidies to producers, increasing investment in research and development (R&D) aimed at improving yields of fresh agricultural produce and at developing technology that reduces food wastage, and increasing transfer payments to rural low-income families. These measures can result in increases in the supply of, and access to, healthy and nutritious food and can thus improve the dietary quality of both urban and rural populations. Increasing investment in R&D of nutritious food production can improve the intake of nutritious and healthy food for 58 percent of urban population and 41 percent of rural population.

3. Adjusting agricultural support policies and promoting the development of green and low-carbon technologies in agriculture can reduce greenhouse gas (GHG) emissions from agrifood systems by approximately 29.1 to 42.4 percent by 2060, while ensuring food security, which also has high economic returns. If it further considers the environmental benefits brought about by the reduction of carbon emissions from agrifood systems, economic returns are even higher.

4. The investment in high-standard farmland construction and green agricultural R&D and extension has a high return, which improves the total agricultural production capacity, reduces inputs and carbon emissions, and has significant positive economic and environmental effects. It promotes the achievement of multiple goals such as food security, economic efficiency improvement, health, and low green carbon. For every 1 yuan invested in high-standard farmland construction, the long-term return of the GDP in the whole industry can reach 10 yuan. In addition, doubling the investment in green technology research and promotion can reduce agricultural carbon emissions by nearly 30%.

5. China's fiscal expenditure on agriculture has narrowed the income gap between urban and rural populations. It has done so by promoting the increase of farmers' incomes, accelerating the transfer of the rural labor force, and promoting the integration of urban and rural industries. The effect of financial support for agriculture in narrowing the income gap between urban and rural areas is more pronounced in underdeveloped areas where agricultural industry support and poverty alleviation expenditure play a greater role.

6. Reducing the minimum purchase price to the amount that can cover the total cost of agricultural production and combine the minimum price with full-cost insurance can increase the efficiency of the government's fiscal expenditures. Under the proposal, the government's fiscal expenditure efficiency can be increased by up to 8.6 times without negatively affecting farmers' grain welfare and changing grain output and import.

Based on the main findings, this report offers the following recommendations:

1. Agricultural support policies should be repositioned to promote a win-win situation of nutrition and health security and green and low-carbon development. Agrifood systems should be transformed in various ways and at multiple levels in order to achieve the major national development goals on health and environment and on carbon peak and carbon neutrality.

2. Support policies should be optimized according to the concept of "Big Food": promote nutrition-oriented food production, diversify food supply and consumption, and reduce the price of nutritious food in order to promote balanced diets and nutritional health. By increasing support to producers of nutritious food and by promoting agricultural science and technology while reducing food loss, the capacity to supply nutritious and healthy food can be enhanced. Transfer payment policies and food subsidy vouchers can also help low-income people improve their food purchasing ability. At the same time, healthy diets should be promoted and nutrition-related diseases prevented through improved dietary guidance and nutrition education; to that end, nutrition knowledge classes should be conducted in rural and urban areas.

3. To ensure food security, agricultural support policies should be transformed such that they pursue green and sustainable development. With that in mind, adoption of agricultural green and low-carbon technologies and research and development (R&D) of breakthrough technologies in agricultural emissions reduction should be further strengthened. This specifically includes the promotion and application of slow and controlled-release fertilizers, deep fertilization machinery, and organic-inorganic compound fertilizers. R&D investment in emerging green technologies such as smart fertilizer, transgenic technology, gene-editing technology, and biological carbon sequestration technology should be vastly scaled up. Furthermore, through financial support and improved mechanism of carbon trading markets, market entities should be incentivized to actively participate in emissions reduction.

4. The structure of agricultural production support should be adjusted to the production of both nutritious and low-carbon foods, i.e., to minimize the tradeoff and maximize the synergy. In addition, more public investment should be allocated to high-standard farmland construction and green agricultural R&D and extension that has the potential

to achieve multiple goals of food systems including food security, nutrition, protection of natural resources and carbon emissions reduction.

5. The expenditure structure and regional distribution of fiscal supports for agriculture should be optimized to promote the goal of common prosperity. Local governments should be encouraged to explore innovative measures that: support agriculture under local conditions; strengthen coordination between fiscal support measures and other policies; increase fiscal support for agriculture in rural areas, especially in underdeveloped areas; improve the inclusiveness of agrifood systems; narrow the income gap between urban and rural population; and promote the integrated development of urban and rural areas to pursue common prosperity.

6. Agricultural support policies should be shifted from the "amber" to the "green" box, so the risk of agricultural trade friction can be reduced and the resilience of agrifood systems can be improved. In this regard, policy innovations must be introduced. The awareness of WTO rules should be enhanced as should the ability to apply these rules, promote and lead WTO reform, reshape international rules, and create a stable and sound new international order.

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Chapter 1

Evolution of Agricultural Support Policies

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Key Findings

- In 2004, China began to introduce a series of agricultural support policies. These policies have been continuously optimized since 2010 through reforms designed to reduce market distortions, increase support for green and sustainable development, and end poverty by 2020. This comprehensive agricultural support system has helped to ensure food security, improve farmers' income, and end hunger and poverty.
- Between 2018 and 2020, agricultural support reached 22 percent of agricultural GDP, which was close to the world average level of 23 percent. While direct production support decreased due to the elimination of policies that distorted market prices, expenditure on general public services was significantly increased, with almost no market distortion effects. Direct support decreased from CNY 359.1 billion in 2015 to CNY 308.2 billion in 2020, with its share decreasing from 53 to 46 percent (2010 constant prices). General services support increased from CNY 316.6 billion in 2015 to CNY 357.6 billion in 2020, with its share increasing from 47 to 54 percent.
- Agricultural support expenditures on resources and environment were still limited by 2020; public spending on agricultural green development was less than 5 percent and public expenditure on nutrition and health was even lower. It is thus difficult to tackle the multiple challenges faced by the agrifood system such as unsustainable use of natural resources, climate change and unhealthy diets. Agricultural support policies must therefore be further optimized.

Policy Recommendations

- The success experiences and lessons of China's agricultural support policy reform in ensuring food security, reducing market distortions, and reducing environmental pollution should be further generalized, and shared globally, especially with developing countries.
- With the objective of guaranteeing food security, the government should consider the multiple goals of China's agricultural support policy by optimizing the expenditure structure, broadening the scope of agricultural support, and improving policy efficiency. These goals include food security, improved diets and nutrition, protecting natural resources, contributing to carbon neutrality, and common prosperity, particularly narrowing rural-urban development gaps.
- Multidisciplinary research collaboration should be enhanced in assessing the impacts of agricultural support policies on food security, nutritional health, natural resources and environment, and inclusiveness and resilience, and also in proposing optimal policy solutions and providing sound scientific references for policymaking.

1.1 Introduction

In recent decades, agricultural support policies in many countries have played an active role in promoting food production and reducing hunger and poverty. Remarkable achievements have been made globally in agricultural production, with rapid growth in output of agricultural products outpacing population growth. Populations' food consumption has increased and the number of undernourished people has decreased significantly. Particularly in China, agricultural reforms that were initiated in the late 1970s have increased farmers' incomes and improved dietary quality. By 2020, China had achieved a moderately prosperous society in all aspects and had eliminated hunger and poverty. This chapter reviews domestic and international agricultural support policies and their impacts. China's experience of developing agricultural support policies has been summed up in order to, on the one hand, provide a reference for other developing countries. On the other hand, China is now implementing new national development goals of nutrition and health, green and high-quality development, common prosperity, and institutional opening. The analysis of the challenges being faced in the course of implementing the corresponding new agricultural support policies can help optimize these policies.

1.2 China's Agricultural Support Policies

1.2.1 Evolution of China's Agricultural Support Policies

Since 2004, to ensure food security and increase farmers' income, China has issued a series of agricultural policies which have been continuously adjusted and optimized to form a relatively comprehensive agricultural policy system. Before 2003, China had been imposing agricultural taxes on farmers. The heavy burden of these taxes resulted in a reduction in grain production. In 2004, China began to abolish agricultural taxes and successfully introduce various agricultural support policies. These included a minimum purchase price policy for rice and wheat and a temporary purchase and storage policy for corn, soybean, and cotton. China also implemented direct grain subsidies, subsidies for superior crop varieties, comprehensive subsidies for agricultural inputs, and subsidies for purchasing agricultural machinery. These policies have effectively incentivized farmers to grow grain and the continuous increase in grain production has, in turn, ensured food security. Grain production increased from 430 million metric tons (Mmt) in 2003 to 680 Mmt in 2021, with an average annual growth of 2.6 percent, record harvests were achieved for 17 consecutive years (National Bureau of Statistics, 2022). China has successfully used 6 percent of the world's freshwater resources and 9 percent of the world's arable land resources to feed 18 percent of the world's population (Economic Information Daily, 2022).

Since 2010, China has made a series of reforms to its agricultural policies, including reducing market-distorting policies on agricultural product prices, increasing support for green and sustainable agricultural development, and increasing expenditure on poverty alleviation. Since then, the costs of agricultural production have continued to rise. The minimum purchase price and the temporary storage price had both distorted the market price, resulting in new structural challenges. They had simultaneously increased output, import, and inventory. The government's financial burden had thus increased, while the effects of agricultural support policies on ensuring food security and increasing farmers' income had weakened. At the same time, the unsustainable utilization of water and soil resources and the excessive use of chemical fertilizers and pesticides from agricultural production activities had exacerbated environmental pollution. The following sections summarize China's major agricultural policy reforms.

First, market price support policies for agricultural products have been reformed to decouple them from production, with the aim of reducing the distortion of agricultural product market prices. Since 2014, the government has gradually abolished temporary policies for purchasing and stockpiling agricultural products such as soybean, rapeseed, cotton, and corn. These policies have been reformed into income transfer, target price, producer, and agricultural insurance subsidies. To date, only the minimum purchase price policies for rice and wheat have been retained, however the amount of these commodities that is being purchased has declined. In 2015, the government merged the "three subsidies" (subsidies for superior crop varieties, the direct subsidy for grain producers, and the comprehensive subsidies for agricultural inputs) into an agricultural support and protection subsidy. Eighty percent of the funds were used to safeguard the soil fertility of cultivated land. The other 20 percent was reserved for comprehensive agricultural input subsidies, incremental funds of the "three subsidies" for agriculture, and pilot subsidy funds that were used to support moderate and large-scale grain producers. Of these, the subsidies for cultivated land fertility protection were distributed on the basis of the contracted land area of farmers. This belonged to the decoupling subsidy and thus had no impact on agricultural production. Policy reform, conducted according to WTO regulations, lowered three subsidies regarded as "amber box" policy, that is (by WTO terminology) policies that needed to be reduced, and raised "green box" (permitted) policies that were decoupled from production. Market distortions were thus reduced while farmers' incomes were at the same time assured.

Second, since 2015, China has issued a package of policies to protect the agricultural ecological environment. These have included: (1) establishment of a strict resource management and conservation system and a resource control system with minimum quotas ("red lines" in Chinese) of permanent basic farmland, water resources, and ecological zones; this improved the efficiency of resource utilization by improving the yield of cultivated land and the utilization efficiency of irrigation water utilization. (2) implementation of a policy to reduce both chemical fertilizers and pesticides; this curbed the overuse of chemical fertilizers and pesticides and subsidized environment-friendly inputs such as organic fertilizers and green pesticides. (3) support for a circular economy approach and development of the recycling of straw, livestock manure, and other wastes. (4) incorporation of binding environmental goals into an incentive and penalty mechanism to strengthen enforcement of environmental laws and to protect resources and the environment.

Third, in order to narrow the urban–rural income gap and ensure the growth of rural incomes, the Chinese government scaled up support for rural low-income groups. It did so by: (1) increasing support for agricultural production in poor areas through the use of poverty alleviation funds that promote the development of local agricultural industries and increase farmers' income. (2) increasing support for rural public services, improving rural education levels and enhancing human capital to accelerate the migration of the rural labor force to non-agricultural sectors. (3) increasing investment in rural infrastructure to promote integrated urban–rural development.

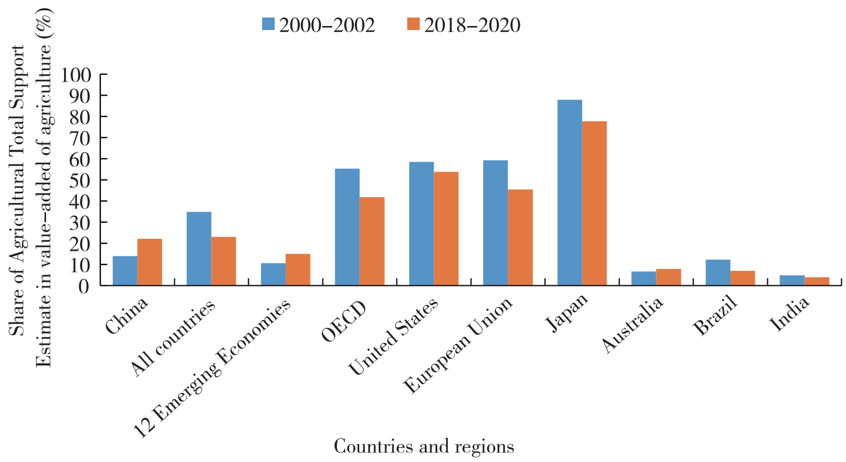
In the last decades, China has opened up in terms of international trade and cooperation. Particularly since joining the WTO in 2001, it has significantly reduced tariffs on agricultural products in order to facilitate agricultural trade. The average import tariffs for agricultural products have decreased from 42% in the early 1990s to 13.8% in 2020. The import tariff quota policies for only certain agricultural products remain, these, include wheat, corn, and rice (OECD, 2021; China's Foreign Trade, 2021). China has signed many regional trade agreements in recent years and has further expanded its openness. In January 2022, the Regional Comprehensive Economic Partnership (RCEP) agreement went into effect, with China promising to: (i) adopt a zero-tariff policy for specific agricultural products such as meat products from member countries, (ii) speed up customs clearance of fresh food, and (iii) enhance trade facilitation.

1.2.2 The Scale and Structure of China's Agricultural Support Policies

China's financial support policies for agriculture include fiscal support policies for agriculture, rural areas, and farmers, with significant disparities in their scope. For international comparison, this study analyzes China's agricultural fiscal support by referencing the evaluation methods developed by the OECD; however, this study focuses on fiscal expenditure on agriculture rather than on non-fiscal support. Using national financial budget account data from the last few years, this chapter summarizes public expenditure on direct support of agricultural production and on general services for agriculture.

Globally, China's agricultural support intensity was at a medium level. According to OECD figures, in 2018–2020 China's total support estimate (TSE) accounted for 22 percent of agricultural GDP (OECD, 2021); this was close to the world average (23 percent), higher than the 12 emerging economies (15 percent), and lower than the percent average of OECD countries (42 percent). In that same time period, the United States and Japan were at 54

Figure 1-1 **Comparison of Agricultural Support Intensity in China and Other Countries**



Source: OECD (2021).

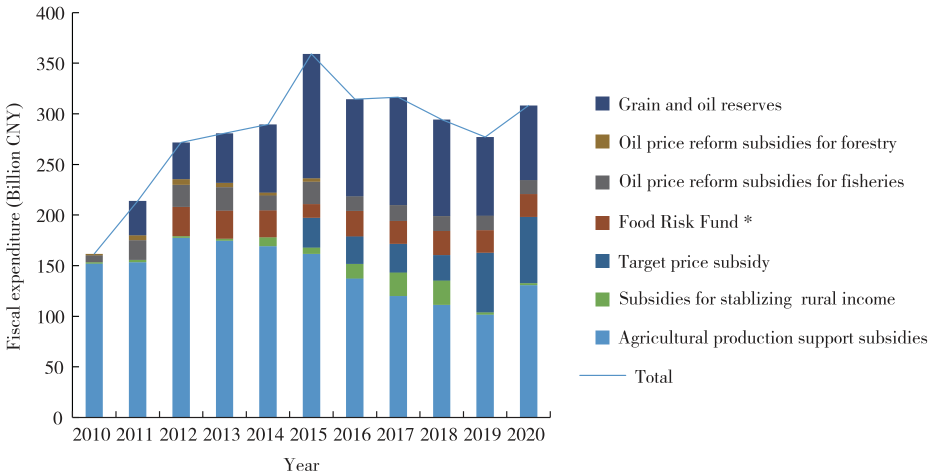
Note: "All countries" refers to the 54 countries (including OECD countries, the EU non-OECD countries, and the 12 emerging economies) that are reported in OECD (2021); EU 2000–2002 reports EU15 countries; EU 2018-2020 report EU27 countries plus the UK.

and 78 percent, respectively (OECD, 2021) (Figure 1-1).

China's agricultural fiscal expenditures are primarily centered on direct support and general service support. Its fiscal expenditures for direct supporting agricultural production mainly include agricultural production support subsidies, target price subsidies, food risk funds, oil price reform subsidies, and subsidies for grain and oil reserves. Agricultural general services support includes infrastructure construction expenditures such as irrigation and water conservancy, rural road construction, rural drinking water for humans and livestock, and farmland construction. It also includes subsidies of public services such as agricultural resource protection and utilization, inclusive financial development, science and technology transformation, extension services on pest control, management of the quality and safety of agricultural products, disaster prevention, subsidies for agricultural structure adjustment, and subsidies for agricultural organization and industrialized management. At 2010 constant prices, the sum of direct production support and general services support for agriculture in China increased from CNY 368.7 billion in 2010 to CNY 613.9 billion in 2020, with an average annual growth rate of 5.23 percent and accounting for an approximately 10 percent share of agricultural GDP. Public expenditure on direct support for agricultural production decreased from CNY 359 billion in 2015 to CNY 277 billion in 2019 and rebounded to CNY 308 billion in 2020, with its share in total agricultural direct public support and general services support decreasing from 53 percent in 2015 to 46 percent in 2020 (Figure 1-2). Public expenditure on general services for agriculture increased from CNY 207 billion in 2010 to CNY 387 billion in 2018 and decreased to CNY 306 billion in 2020, with its share increasing from 47 percent in 2015 to 54 percent in 2020 (Chen and Zhang, 2021) (Figure 1-3). The main reason for the changes is that some direct subsidies were transformed into public service expenditures, which were decoupled from agricultural production (Chen and Zhang, 2021).

Public expenditure on direct support for agricultural production showed an increasing trend before 2015 and a decreasing trend in subsequent years, as shown in Figure 1-2. The four points about the components of public expenditure on direct support for agricultural production are being made here. First, subsidies supporting agricultural production—including subsidies for superior crop varieties, direct subsidies for grain producers, and comprehensive subsidies for agricultural inputs—increased from CNY 152 billion in 2010 to CNY 162 billion in 2015, with an average annual growth of 1.2 percent. As mentioned in Section 1.2.1, after the adjustment in 2015 the expenditure showed a downward trend. By 2020, however, it rebounded again to CNY 131 billion. Second, the expenditure on grain and oil reserves increased substantially, moving from CNY 34 billion in 2011 to CNY 123 billion in 2015, with an average annual growth of 38 percent. Due to the gradual cancellation of the temporary purchasing and stockpiling policy for maize, cotton, rapeseed, sugar, etc. that began in 2014, from 2015 to 2020 the expenditure on grain and oil reserves decreased to CNY 74 billion. The minimum purchase price expenditure is the most important item in grain and oil reserve expenditures. By 2020, the minimum purchase price expenditure was CNY 32 billion, accounting for 43 percent of the total grain and oil reserve expenditure. Third, the target price subsidy is used mainly to subsidize cotton production in Xinjiang. Between 2015 and 2018, the expenditure was stable at CNY 25–29 billion and in 2020 it increased to CNY 65 billion. Fourth, the grain risk fund was used mainly to stabilize the grain market, and the expenditure fluctuated around CNY 25 billion. Fifth and finally, the oil price subsidy expenditure has fluctuated slightly in recent years, reaching CNY 13 billion in 2020.

Figure 1-2 The Fiscal Expenditure for Direct Supporting Agriculture (2010 Constant Price, Billion CNY)



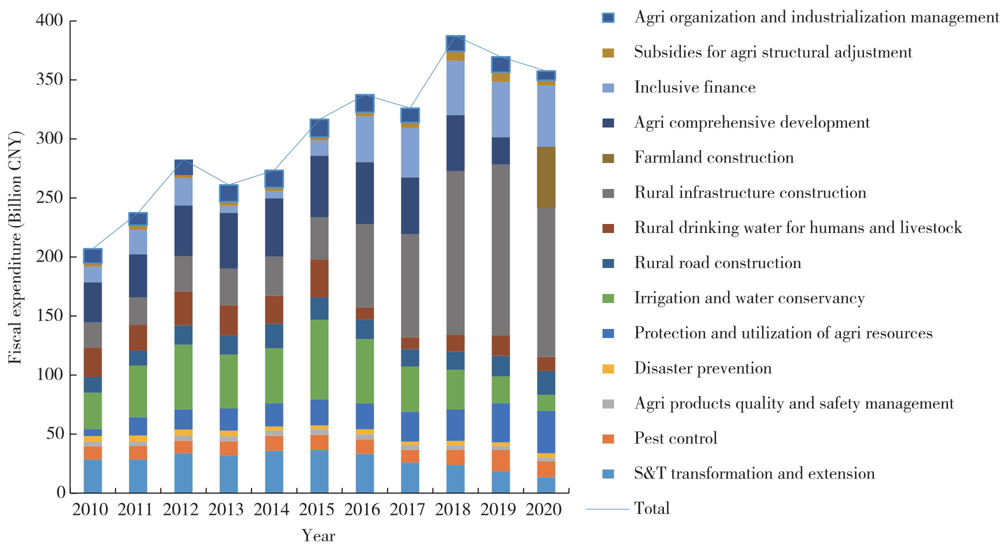
Source: 2010–2019 data from Chen and Zhang (2021), the original data, and the data in 2020, is from the Ministry of Finance National General Public Budget Expenditure Final Account (2010–2020).

Note: * The 2010–2015 Food Risk Fund removed direct grain subsidies and consolidated them into agricultural production support subsidies to reflect the continuity of the three subsidies and of agricultural production support subsidies.

Among public expenditures for supporting general agricultural services, there was a rapid increase in expenditures on rural infrastructure construction and on comprehensive agricultural development, farmland construction, protection and utilization of agricultural resources, and inclusive financial development (Figure 1-3). Rapid increase in expenditures on infrastructure construction in rural and underdeveloped areas. From 2010 to 2020, these expenditures increased from CNY 21 billion to CNY 126 billion, an increase by about 6 times in 10 years; over this period, the fastest growth was seen between 2015 and 2019, during which it increased from CNY 36 billion to CNY 145 billion—an average annual growth rate of 42 percent. Expenditure on comprehensive agricultural development increased from CNY 25.8 billion in 2008 to CNY 52.7 billion in 2016, it again decreased after 2017, reaching CNY 23.1 billion by 2019. In 2020, CNY 52 billion was spent on farmland construction. The government also increased its investment in protecting the agricultural environment and resources. Expenditure on the protection and utilization of agricultural resources increased from CNY 6 billion in 2010 to CNY 36 billion in 2020, with an average annual growth of 20 percent. This was mainly used to protect the quality of cultivated land and grassland. From 2010 to 2018, inclusive financial development expenditure increased from CNY 13 billion to CNY 46 billion. [1] The agricultural insurance subsidy is the most important support item among inclusive financial development expenditures. From 2010 to 2018, it increased from

[1] Expenditure on inclusive finance development from 2010 to 2012 was calculated using agricultural production insurance subsidies and rural financial development expenditure, and expenditure from 2019 to 2020 is the residual value of expenditure on agriculture, forestry and water conservancy minus the sum of all listed sub-items.

Figure 1-3 **Fiscal Expenditure on General Public Services Support for Agriculture in China (Constant 2010 Prices, Billion CNY)**



Source: 2010–2019 data are from Chen and Zhang (2021); the original data, and 2020 data, are from the Ministry of Finance, National General Public Budget Expenditure Final Account (2010–2020).

CNY 11 billion to CNY 32 billion, with an average annual growth rate of 14 percent, which accounted for over 50 percent of inclusive financial development expenditure. Expenditure on science and technology transformation and extension services increased from CNY 28 billion to CNY 37 billion between 2010 and 2015 and gradually decreased after 2015. By 2020 it had dropped to CNY 13 billion.

In recent years, the government has paid increased attention to the agricultural ecological environment. Public expenditure on the agriculture-related ecological environment has also increased rapidly, moving from CNY 93 billion in 2010 to CNY 186 billion in 2019, with an average annual growth rate of 8%. However, total support remains limited, with expenditure at only CNY178 billion in 2020. Public expenditure on the agriculture-related ecological environment includes two main parts: (1) direct subsidies, which include subsides directed at returning farmland to forest and grazing land to grassland, and forest ecological benefit compensation; and (2) general services expenditures, which mainly include expenditures on agricultural resource protection and utilization, protection of the natural ecological environment, control of desertification, nature reserves, animal and plant protection, wetland protection, sand control and prevention of desertification, prevention of forestry related disasters, water and soil conservation, and water resource management and protection. Cui et al. (2018) compared Chinese and European Union (EU) public support for agricultural green development; they found that in the EU, about 40 percent of agricultural support expenditures were related to green development, while in China the share was below 5 percent.

1.2.3 The Impact of China's Agricultural Support Policies

Agricultural support policy plays an important role in ensuring food security, and increasing farmers' income. and agricultural-related public expenditure improves total factor productivity and agricultural output (Gong and Wang, 2021; Fan et al., 2018; Gao et al., 2016; Qian and Zhao, 2015). Among the policies for supporting agriculture, the minimum purchase price of grain plays an important role in ensuring grain production (Zhou and Zeng, 2019; Cao et al., 2017). Researchers have also argued that since the distribution of subsidies for supporting agricultural production was based on contracted land area, the subsidies did not impact agricultural production (Huang et al., 2011). Other studies showed that agricultural support policies increased farmers' income, alleviated poverty, and narrowed the income gap between urban and rural residents (Fan et al., 2018).

The agroecological environment support policies have many positive effects. The "Grain for Green" project promoted afforestation, optimized land use structure, and increased carbon sink (Deng et al., 2017). The measures implemented as part of the "double reduction" policy for chemical fertilizers and pesticides also achieved remarkable results, showing a significant decrease in the use of chemical fertilizers and pesticides (Jin et al., 2018). Agricultural subsidies have facilitated the extension of green technologies such as the use of organic fertilizer, straw returning techniques, and agricultural waste recycling (Liu et al., 2021; Qiu et al., 2020; Dong et al., 2019). Agricultural producer subsidies that include environmental protection requirements can guide farmers in the adoption of environmental friendly technologies that have significant environmental benefits and promote green agricultural development, while at the same time ensuring robust agricultural output (Luo et al., 2013).

Some research claims, however, that agricultural support policies have negative impacts on the environment. The agricultural subsidies distorted the input market, which resulted in excessive use of chemical fertilizers and pesticides (Yang and Qiao, 2018; Yu et al., 2017). Although agricultural subsidies may help increase planting areas, it may also lead to the exacerbation of agricultural non-point source pollution (Wu and Miao, 2017).

At the same time, agricultural support policies have rarely considered the impacts on nutrition and health. The policies effectively promoted grain production and have thus solved the problem of the supply of staple food. However, the support for the production of other nutritious and healthy foods is insufficient. They are therefore not adequately addressing new challenges such as increased overweight and obesity among residents (Chen et al., 2019). Agricultural support policies thus need to be reformed to help improve the nutritional health of residents.

1.3 Global Agricultural Support Policies

The current scale and intensity of global agricultural support is substantial. It is primarily supported through market price, however, with little expenditure on general services support, and most agricultural support has been used to produce specific agricultural products (mainly cereals). OECD (2021) figures, which are based on data from 54 countries, indicate that agricultural support totals were about US$ 720 billion annually for 2018–2020, of this, more than one-third (US$ 272 billion) was paid by consumers in the form of market price support, while the remaining US$ 447 billion came from fiscal expenditures. About three-quarters of the total (US$ 540 billion) was producer support (PSE) and US$ 102 billion came from general services (GSSE) support, the latter included US $76 billion for R&D, biosecurity, and public investment in infrastructure. Consumer subsidies (for example for food assistance programs) came to about US$ 78 billion annually, that is, about 11 percent of total agricultural support. Based on data from 88 countries, the Ag-Incentives Consortium showed that the average support for producers in these countries from 2013 to 2018 was around US$ 540 billion per year, accounting for 15 percent of their agricultural GDP (PIM, 2021; FAO et al., 2021a). Although general services subsidies were considered to be the most conducive to sustainable development, they were only equivalent to one-third of the total market price support (MPS) (FAO et al., 2021a). With regard to types of supported products, 70 percent of total global agricultural support was used to support cereals production.

There were significant differences among countries and regions. The agricultural support in middle- and high-income countries and regions, and support in middle-income countries were relatively high and increased rapidly. In low-income countries, however, the level of support was low or even negative (OECD, 2021). The level in high-income countries, although high, showed a downward trend. It moved from 45 percent in 2005 to 20 percent in 2014, but then increased to approximately 30 percent in 2018. In middle-income countries, agricultural support has increased rapidly, the ratio of producer support to agricultural GDP increased from almost 0 percent in 2005 to 14 percent in 2015 and then gradually decreased to about 10 percent in 2018 (FAO et al., 2021a). The main reasons for the decline of agricultural support in high- and middle-income countries were the reduction in market price support and the increased decoupling of agricultural support, such as general services support (OECD, 2021). Governments tend to curb the prices of food and agricultural products in low-income countries, and agricultural producer support is generally negative (OECD, 2021).

Global agricultural support policies influence agricultural production through their effects on production patterns, farming practices, and the use of inputs, this, in turn, has an impact on farmers' livelihoods, nutritional health, and the environment (DeBoe, 2020; OECD, 2021). Agricultural support policies enable producers to purchase more inputs, while market price support incentivizes the expansion of agricultural production, which results in increased agricultural output. General service support policies such as for agricultural R&D and for extension and infrastructure construction can improve the total factor productivity of agricultural production. These support policies have contributed to unprecedented growth in agricultural output (OECD, 2021), while agricultural support policies have played an important role in alleviating residents' malnutrition. Globally, the undernourished population decreased from 800 million in 2005 to 600 million in 2014, and the incidence of malnutrition decreased from 12.4 percent in 2005 to 8.3 percent in 2015 (FAO et al., 2021b). However, due to the impacts of regional conflicts, climate change, and COVID-19, malnutrition has again worsened, rising to 9.9 percent in 2020, and the number of malnourished people has again risen to 768 million (FAO et al., 2021b).

Although support policies have played an important role in ensuring food security and increasing farmers' income, the challenges were gradually exposed after the 1990s. On the one hand, they manifested in resource mismatch from distorted market mechanisms, in increased greenhouse gas emissions, and in expanded non-point source pollution caused by excessive application of chemical fertilizers, pesticides, and other inputs. On the other hand, agricultural support policies have faced challenges such as the need to address nutritional imbalance, overweight/obesity, and the related non-communicable diseases, widening income gaps, and their insufficient inclusion of poor smallholder farmers.

To achieve the United Nations Sustainable Development Goals (SDGs), it is imperative to reoptimize global agricultural support policies. The SDGs provide directions for national agrifood systems to transform themselves toward efficiency and health for both humans and the environment. General services support policies can be used to promote technologies that improve total factor productivity and support the construction of infrastructure that is conducive to increased yield and reduced waste. Such policies can be used to improve food supply, obtain higher benefits from agricultural research investment (Alston et al., 2022), and realize sustainable agricultural development. Increased investment in infrastructure such as roads, irrigation, electricity, and machinery can help farmers establish connections with the market and improve agricultural labor productivity (OECD, 2021).

1.4 Challenges of China's Agricultural Support Policies

In the past two decades, China's agricultural support policy has improved food security and increased farmers' income. In recent years, China has successfully implemented a series of reforms that have been conducive to achieving the SDGs. These experiences should be summed up and could provide a reference for developing countries. China's agrifood systems, however, still face multiple challenges. First, the unbalanced dietary structure and nutrition of its population, as well as overweight/obesity and the related non-communicable diseases constitute a heavy burden for society. Second, agricultural production has faced severe environmental problems such as the inadequate supply and degradation of water and soil resources, the intensification of environmental pollution and greenhouse gas (GHG) emissions, and the tightened resource and environmental constraints of agricultural production. Third, the income disparity between urban and rural residents remains significant. Fourth, linkages between Chinese and world agricultural markets have become closer and the risks of the international trade in agricultural products have been exacerbated by an increasingly complicated international economic and trade environment and the aggravated constraints of WTO rules. Optimizing agricultural support policy to promote agrifood system transformation has therefore become an important topic in China and in other countries. China's current agricultural support policies, however, cannot meet the requirements of this new national economic development ambition, nor can they cope with the new challenges of the agrifood system.

Severe challenges thus persist with regard to agricultural support policy.

First, while fiscal expenditures on supporting agriculture are increasing, the multiple goals of national economic development in the modern era put forward to a higher request for agricultural supports. The current agricultural support is difficult to achieve the transition to more nutritious, low-carbon, inclusive, and resilient agrifood systems.

The second challenge lies in its focus on staples, with little support for other nutritious, healthy, and low-carbon foods. At present, Chinese residents consume an unbalanced diet that consists primarily of cereals, with excess intake of edible oils, and red meat, and insufficient intake of vegetables, fruits, and aquatic and dairy products. It is urgent that agricultural policies be optimized to support the production of nutritious and healthy food and to improve its affordability. The government should guide the transformation of dietary patterns toward nutrition and health in order to reduce the risks of overweight/obesity and the related non-communicable diseases.

Third, while China's agricultural support policies have expanded support for green agricultural production, they are still insufficient to meet the goals of carbon peak, carbon neutrality, and green development. To support agriculture's green and low-carbon development, there needs to be made agricultural policies of environmental- friendliness.

The fourth challenge is that, while fiscal support has boosted investment in public services, enhanced the capacity of agricultural production, and improved rural living conditions, basic public services are still unevenly distributed across urban and rural areas and the rural–urban development disparity remains significant. So far, most fiscal support policies have favored large-scale operations. To protect smallholder farmers, it is vital to encourage the inclusive development of modern agriculture by intensively involving smallholder farmers.

Fifth, the WTO's international trade rules have set limits on China's agricultural domestic support policy. Since 2004, China's agricultural support policies have intensified their support of the sector. "Amber box" support of staple grains, in particular, has reached close to its upper limit. China's agricultural support policy must therefore be further transformed so that domestic agricultural policies are in line with international rules in the context of institutional opening, while still ensuring domestic food security.

Finally, multidisciplinary research collaboration should be enhanced in order to comprehensively assess the impacts of agricultural support policies on food security, nutrition and health, resources and environment, and inclusiveness and resilience. This should be done according to the multiple national development goals and the new requirements for agrifood system transformation. Optimal solutions and comprehensive scientific references should be proposed to the government in order to maximize the effectiveness of policy decision-making.

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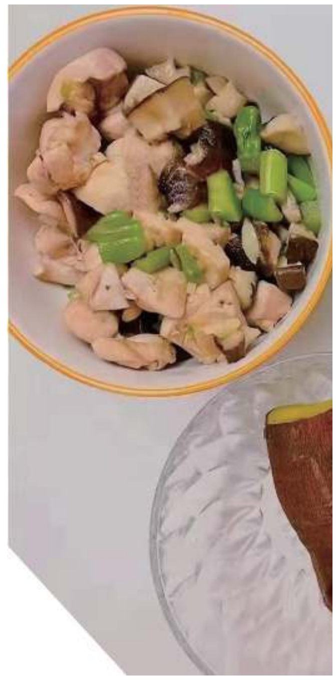
Chapter 2



Reforming Support Policies to Improve Chinese Nutrition and Diet

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Key Findings

● The dietary structure of China's urban and rural populations has improved remarkably, however, unbalanced food intake persists and has even worsened for certain population groups. This includes excessive intake of cereals, edible oil, red meat, and highly processed foods, and insufficient intake of fruits, vegetables, aquatic products, and dairy products. Unbalanced diets are particularly worse for rural population.

● A number of support policies could boost the production and consumption of nutritious and healthy food. They include increasing producer subsidies and income transfers to rural low-income residents and enhancing the extension of technology as well as investment in research and development (R&D). Despite the long-time lag, the benefits of R&D investment are favorable in production at nutritious foods. Investment in R&D has a particularly large impact on improving the dietary quality of urban and rural populations. Results show that increasing R&D investment can lead to improved intake of fruits, vegetables, aquatic products, and milk for 58 percent of urban residents and for 41 percent of rural residents.

● Policies aimed at increasing production of nutritious and healthy food and enhancing food affordability can improve dietary quality and improve nutrition and health. However, It is difficult to completely change food consumption behavior using only economic measures, given the many factors that affect the choice of foods. It is thus necessary to combine guidance on healthy eating with national nutrition education.

Policy recommendations

● Dietary requirements for nutritious and healthy food should guide the transformation of the food production structure. The production capacity for nutritious and healthy foods can be increased through augmenting production subsidies, raising R&D investments, and reducing the wastage of fresh agricultural products.

● China needs to implement income transfers to low-income people to improve their ability to obtain nutritious and healthy food and thus also improve their dietary quality and health. The gap in dietary quality between urban and rural populations could then be narrowed and the goal of national nutrition and health could be achieved.

● Dietary guidance and nutrition education need to be strengthened. Public nutrition knowledge should be popularized so that it guides people to have balanced diets, improve their diet and nutrition, and prevent and control nutrition-related diseases.

2.1 Introduction

On March 6, 2022, at the Fifth Session of the Thirteenth National Committee of the Chinese People's Political Consultative Conference, Chinese President Xi Jinping emphasized that China needs to improve the lives and livelihoods of its people and to ensure an adequate food supply by providing enough meat, vegetables, fruit, and aquatic products for healthy diets. Understanding the changing trends of people's dietary structure and encouraging people to eat more healthily is central to establishing the "Big Food" concept. The country should actively promote reform of the agricultural supply side in order to achieve a balance between the supply of, and demand for, various types of food and to better meet the increasingly diversified food consumption needs of the people.

China has always attached great importance to agricultural development. Particularly since 2004, a series of policies have been issued to support agricultural development. These have stimulated farmers' enthusiasm for growing grain, improved agricultural productivity, and effectively ensured the supply of grain and agricultural products. Support policies have played an important role in promoting agricultural development and improving nutrition and health. The amount of food consumed by both urban and rural populations in China has increased significantly, the dietary structure has gradually diversified, the dietary energy intake is sufficient, high-quality protein intake has continued to increase, and the problem of rural undernutrition has been steadily improved. The current diet of Chinese people, however, is facing new challenges. These include an unbalanced dietary structure and nutritional intake that is due to excessive intake of edible oil and highly processed foods; insufficient intake of fruit, aquatic products, and dairy products; and lack of awareness of nutritious and healthy lifestyles. As a result, the incidence of nutrition-related chronic diseases is showing an upward trend.

Nutrition-related diseases caused by unbalanced dietary structure and nutrient intake pose a serious threat to the health of people and a significant burden to economic development. The problem of overweight/obesity has become increasingly prominent; among all age groups in urban and rural areas the rate continues to rise to the point where, currently, over half of adults are overweight or obese. In some key regions and among certain key populations such as infants and young children, women of childbearing age, and the elderly, the problem of deficiencies in important micronutrients is prevalent (National Health Commission, 2020). China's incidence of cardiovascular and cerebrovascular diseases, cancer, chronic respiratory diseases, diabetes, and other chronic diseases now account for 88% of the total number of deaths (National Health Commission, 2020).

In response to this, China's food production is entering a new stage of nutrition-oriented development, and agricultural production is being transforming from a survival-oriented food supply to meet nutritional and health needs. The transformation of the agricultural and food (Agrifood) system is the basis for ensuring national nutrition and food security and is key to achieving comprehensive improvements in national health and well-being. Of particular urgency is the need to optimize support policies. This chapter systematically reviews the changes in food consumption, nutrient intake, and dietary quality of Chinese urban and rural populations over the past 20 years. It compares the differences in food and nutrient intake between urban and rural populations and between members of various income groups. It uses the China Agricultural University's Agrifood Systems model (the CAU-AFS model) to analyze reform options. The model simulates the impact of different support policies on the food consumption and dietary quality of urban and rural populations from the supply and demand sides; it also explores how to optimize future support policies to better serve nutrition and health goals.

2.2 Evolution of nutrition-related policies and their impact

Support policies play an important role in advancing agricultural development. The sustainable development of agriculture and its important role in the dimension of nutrition and health has become the focus of international agricultural policy. From 2004 to 2022, China successively issued 19 "No. 1 Central Documents" concerning agriculture, rural areas, and farmers, gradually establishing and improving the agricultural policy framework. China's agricultural support policies, however, started later than those of other countries and its overall consideration of agricultural policy and nutrition and health policy is still in its infancy.

The WTO's Global Strategy on Diet, Physical Activity and Health – 2004 pointed out that agricultural policies usually have a huge impact on the national diet; this document urges member states to consider nutrition and health in the process of formulating agricultural policies. The US Agriculture Reform, Food, and Jobs Act of 2013 reformed intensive nutrition programs to provide millions of low-income families with adequate food through supplemental nutrition assistance programs and emergency food assistance programs. In 2020, Germany, as the then president of the Council of the European Union, released a document entitled Sustainable Food Policy: Formulating a Comprehensive Food Policy and Creating a Fair Food Environment, thereby leading the transformation of the EU's agricultural policy into a (comprehensive) food policy that suggested large-scale adjustments and stronger nutrition policies for sustainable food environments.

The 19th National Congress of the Communist Party of China made major decisions and deployments to implement the Healthy China strategy. It improved national health policies, provided all-around and full-cycle health services for people, and issued a series of nutritional support policies. In July 2017, the General Office of the State Council issued the National Nutrition Plan (2017–2030) to develop the food nutrition and health industry, develop and utilize China's rich resources of agricultural products, and increase efforts to promote the production of nutritious and high-quality agricultural products. The National Strategic Plan for Promoting Agriculture by Quality (2018–2022) clarifies that by 2022 the supply of high-quality agricultural products need to be greatly increased, with better taste and quality, more balanced nutrition, and more distinctive features; it should effectively satisfy consumer demand for individualization, diversification, and high quality. The China Food and Nutrition Development Outline (2021–2035), which is being compiled by the Ministry of Agriculture and Rural Affairs and the National Health Commission, is an important part of promoting the development of high-quality agriculture and ensuring the effective supply of important agricultural products. It is an important starting point for the implementation of the Healthy China strategy and provides a basis for the development of "nutritional agriculture".

Globally, a range of supportive policies that focus on nutrition and health are gradually transforming food systems toward healthy diets for all. On the demand side, consumers are being guided through subsidies, taxes, and food labels to form an awareness of, and to optimize, healthy and good-quality diets. Germany, for example, has guided consumers to reduce the consumption of animal products by abolishing reductions of, and exemptions from, the consumption tax on animal products; it is gradually replacing the consumption of animal products with vegetables and soy products and is encouraging the formation of a dietary structure that is beneficial to health and the environment (Yu et al., 2021).

2.3 Food intake structure and dietary quality of Chinese urban and rural populations

With the development of the economy and the improvement of incomes, the food consumption structure of Chinese people has undergone tremendous changes. This chapter uses data from the National Bureau of Statistics and Fixed Observation Points in Rural Areas to reflect the changes in food consumption structure, nutrient intake, and dietary quality of Chinese people over the past two decades; figures from the data base are used to calculate the average daily intake of various foods, macronutrients, and micronutrients. The Chinese Dietary Balance Index (DBI) was used to further evaluate dietary quality, and comparisons were made of the differences in food consumption structure, nutrient intake, and dietary quality among members of various income groups.

Data on the estimated food and nutrient intake of urban and rural populations in this chapter are compared with data from the Report on Nutrition and Chronic Disease Status of Chinese Residents 2020. Data from the National Bureau of Statistics (National Bureau of Statistics, 2001-2021) is adjusted for the proportion of residents eating out (eg. eating in restaurants) and is added to the latest data for longitudinal comparisons. Calculations based on the combined data from the above sources suggests that the main food consumption patterns of urban and rural populations are consistent over the same or similar years.

2.3.1 Food intake of urban and rural populations in China

This chapter uses data from the Urban Household Survey of the National Bureau of Statistics and Fixed Observation Points in Rural Areas to calculate the standard average daily intake of various foods by urban and rural populations in 2000, 2010, and 2020. Recommended food intake patterns for a balanced diet are compared, and differences between various income groups are analyzed. The results show that between 2000 and 2020, the dietary structure of urban and rural populations has changed quite significantly.[1] The gap between food intake and the values recommended by the dietary guidelines for the respective food groups was also considerable. The overall observations are as follows:

Both urban and rural populations have unbalanced diets. On the one hand, there is an excessive intake of cereals and tubers,[2] edible oil, and red meat. In 2020, the intake of cereals and tubers by rural residents exceeded the recommended values from the dietary guidelines by 52.5%. The intake of edible oils by urban and rural populations had also increased significantly over the 20 years of the study. The intake of edible oil was observed to be higher than the recommended value of the dietary guidelines for urban and rural populations by 48.3% and 62.5%, respectively. Urban and rural populations were also observed to have an excessive intake of red meat;[3] the overconsumption of red meat by urban residents was more serious than that of rural, and in 2020 it exceeded the values recommended in the dietary guidelines by 58.3%. The intake of vegetables, fruit, aquatic products, eggs, and dairy products, on the other hand, has been insufficient for a long time and the rate of increase is small. The problem of insufficient food intake by rural residents needs further attention. Although the vegetable intake of urban and rural populations has increased over the past 20 years, in 2020, it was still lower than the recommended value by 25.2% and 38.3%, respectively. Over the period of the study, the intake of fruit, aquatic products, and dairy products in urban and rural areas had not increased. In 2020, the intake of fruit and aquatic products by urban residents was 50% lower than the recommended value, and that of rural residents was about 80% lower. The intake of dairy products by urban residents was 80% lower than the recommended value,

[1]In this study, the energy intake level of the converted standard person is 2,250 kcal (the standard of light physical labor for men aged 18–50 years). It compares the standard person average daily intake of various food groups with recommended values from the Chinese Dietary Guidelines 2016, in the balanced dietary pattern with reference to the 2,200 kcal energy intake level. The daily intake of various food groups is compared as follows: cereals and tubers: 275 g/person, livestock and poultry meat: 75 g/person, edible oil: 25 g/person, vegetables 450 g/person, fruit 300 g/person, aquatic products 75 g/person, dairy products 300 g/person, and eggs 50 g/person.

[2]Rice and flour accounted for more than 95% of the cereals and tubers consumed in 2000 and 2010; this had decreased to 90% by 2020.

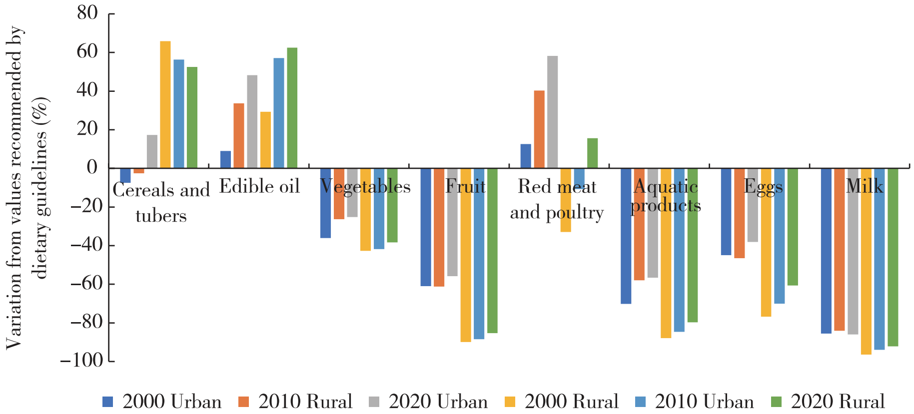
[3]Meat consumption includes mainly red meat (pork, beef, and mutton) and poultry. In 2000 and 2010, red meat accounted for more than 80% of the meat consumed; this is expected to decrease in 2020, but to still account for more than 70% of meat consumption.

and that of rural residents was 90% lower (Figure 2-1). Such insufficient intake is serious.

There are significant differences in food consumption between urban and rural populations and between residents of different income groups. The results of a 2020 comparison between the food intake of members of different income groups in urban and rural areas of China in terms of consumption recommended by the dietary guidelines is shown as follows. The low-income group has a seriously excessive intake of cereals, tubers, edible oil, and red meat. Except for the urban high-income group, all other income groups consume excessive amounts of cereals, tubers, and edible oil. Among them, the rural low-income group has the most excessive consumption of cereals and tubers and the urban low-income group consumes excessive edible oil and red meat. Members of both urban and rural high- and low-income groups consume insufficient vegetables, fruit, aquatic products, eggs, and dairy products. Compared with other income groups, the rural low-income group's intake of fruit, aquatic products, eggs, and dairy products is particularly insufficient (Figure 2-2).

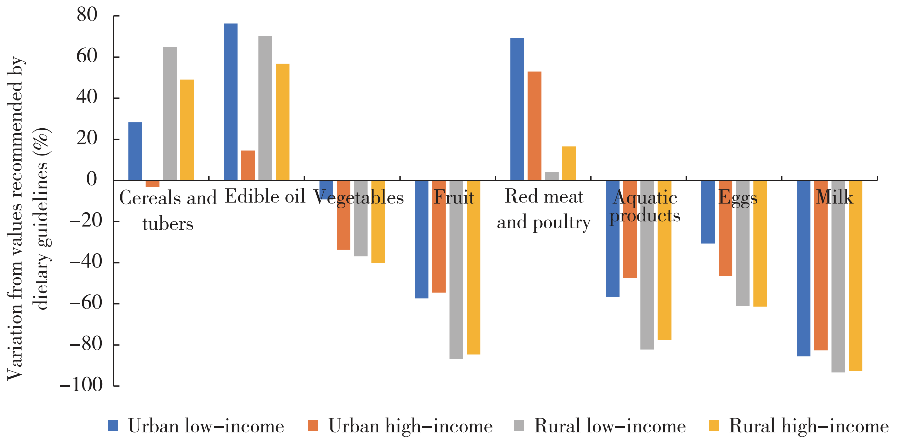
The above analysis shows that income has a relatively small impact on the red meat and poultry consumption of urban and rural populations. With an increase of income, urban residents' excessive intake of

Figure 2-1 Comparison of Food Intake of Chinese People with the Recommendation by Dietary Guidelines, 2000 to 2020



Source: Urban data comes from the survey data of urban households by the National Bureau of Statistics; rural data comes from the Fixed Observation Points in Rural Areas survey; data for 2020 is calculated based on 2015 data and food consumption data from the National Bureau of Statistics.

Figure 2-2 Comparison of Food Intake Between High and Low-income Groups of Chinese People with the Recommendation by Dietary Guidelines in 2020



Source: Urban data is from the National Bureau of Statistics of the Urban Household Survey; rural data is from Fixed Observation Points in Rural Areas; 2020 data is calculated based on 2015 data and food consumption data from the National Bureau of Statistics.

Note: Urban and rural populations are divided into five equal parts according to disposable income, with the lowest-income group and the highest-income group being selected for the analysis.

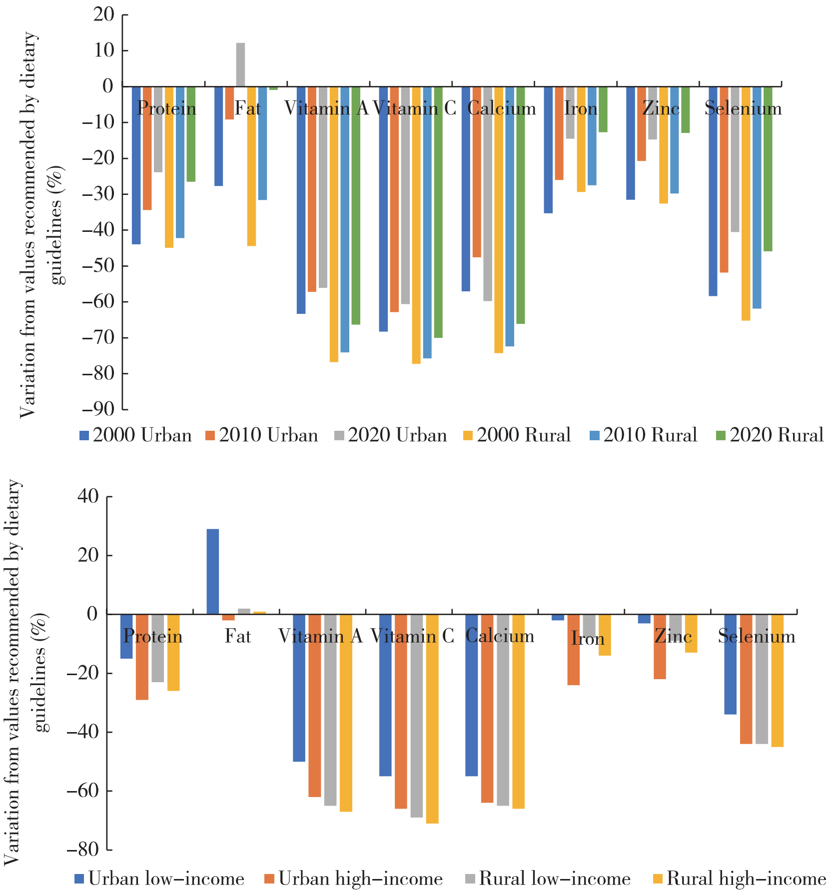
red meat is declined, but the higher the income of rural residents, the greater the intake of red meat. Both urban and rural populations also have insufficient intake of fruit, aquatic products, and dairy products; this is especially the case for rural residents with low incomes. Appropriate support policies should be adopted to improve the dietary quality of rural low-income residents.

2.3.2 Macro and micronutrient intake of urban and rural populations in China

This section uses the Standard Edition of the Chinese Food Composition Table (6th Edition) to convert the standard average daily intake of macro and micronutrients for urban and rural populations in 2000, 2010, and 2020; it compares the results with the Chinese Dietary Guidelines 2016 in the balanced dietary pattern.[4] This section compares macro and micronutrient intake and finds that between 2000 and 2020, the intake of macronutrients by Chinese urban and rural populations (protein, fat, and carbohydrates) and their consumption of micronutrients (vitamin A, vitamin C, calcium, iron, zinc, and selenium) were significantly different from those recommended by the dietary guideline. In general, the pattern presents the following characteristics (Figure 2-3).

The consumption of protein and fat is increasing

Figure 2-3 Comparison of Nutrients of Chinese People by Rural and Urban and by Income



Source: Urban data comes from the National Bureau of Statistics urban household survey data; rural data comes from Fixed Observation Points in Rural Areas data; the 2020 data is calculated based on the 2015 data and the food consumption data of the National Bureau of Statistics.

Note: By converting the number of standard households, the per capita daily nutrient intake is converted; "difference ratio" refers to the ratio of the difference between the nutrient and the standard value to the standard value. Protein, fat, and carbohydrates are measured in unit g/day, vitamin A in unit μg/day, vitamin C in unit mg/day; calcium, iron, and zinc in unit mg/day; and selenium in unit μg/day. After dividing urban and rural populations into quintiles according to their disposable income, the lowest-income group and the highest-income group were selected for the analysis.

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[4] In this study, the energy intake level of the converted standard person is 2,250 kcal (the standard of light physical labor for men aged 18–50 years). The standard person average daily intake of macro and micronutrients compare with the recommend value of the Chinese Dietary Guidelines 2016 in the balanced dietary pattern with reference to the 2,200 kcal energy intake level. The daily intake of macro and micronutrients is compared as follows: protein 86 g/person, fat 75 g/person, vitamin A 766 μg/person, vitamin C 187 μg/person, calcium 859 mg/person, iron 22.6 mg/person , zinc 12.8 mg/person, selenium 64.9 μg/person.

and the increase is large. While the protein intake of urban and rural populations is increasing, in 2020 it was still 20% lower than the recommended value. The fat intake of urban and rural populations has increased rapidly. For urban residents, it increased from 28% below the recommended value of the dietary guidelines in 2000, to 20% above the recommended value by 2020; during the same time period, the fat intake of rural residents increased from 44% below the recommended value to 4.4% above the recommended value by 2020. Further, there has been long-term insufficient intake of vitamin A, vitamin C, calcium, and selenium among urban and rural populations, with intake values more than 50% below the recommended value of the dietary guidelines, a serious insufficiency.

The per capita disposable income of urban and rural populations is divided into five equal parts, with the highest 20% designated as the high-income group and the lowest 20% as the low-income group. In terms of the nutrient intake of residents by income group, at the macronutrient level urban low-income residents have 31.5% higher fat intake than urban high-income residents, which is 29% higher than the recommended value. In terms of micronutrients, the calcium, iron, and zinc intakes of urban and rural populations in the low-income group were higher than those in the high-income group. The calcium, iron, and zinc intakes of urban low-income residents were higher than those of high-income residents by 24.1%, 29.0%, and 24.5%, respectively, the reason possibly being that urban low-income residents consume more red meat. The differences in calcium, iron, and zinc intakes of rural high- and low-income groups, however, were smaller, possibly because urban and rural populations generally consume excessive amounts red meat and edible oil. The lack of vitamin A and vitamin C may be due to insufficient intake of fruit and vegetables and the lack of calcium is mainly due to insufficient intake of dairy products, tofu and soy milk.

2.3.3 Dietary quality of Chinese urban and rural populations

This section uses the Dietary Balance Index (DBI) to evaluate the quality of Chinese urban and rural diets. The latest version of the DBI is DBI-16 (He et al., 2018). DBI-16 comprehensively evaluates the dietary quality of Chinese people based on the Chinese Dietary Guidelines 2016 and Chinese Food Guide Pagoda. Compared with the Healthy Eating Index (HEI), which uses the American dietary guidelines as the standard, DBI-16 is more in line with the actual dietary nutrition status of Chinese residents. Compared with the HEI, DBI-16 can obtain the levels of over- and underconsumption by calculating the high bound score (HBS) and low bound score (LBS); it can thus more intuitively and comprehensively reflect the problem and degree of unbalanced intake in the dietary structure. The scoring method of DBI-16 is suitable for all healthy people except infants and young children under two years of age; it is not suitable for people with special nutritional needs, such as pregnant women, lactating women, and the elderly, as their nutritional needs are different from those of the general population (He et al., 2018). DBI-16 is also based on the Chinese Dietary Guidelines 2016 and on Chinese Food Guide Pagoda 2016, which is not convenient for international comparative analysis. DBI-16[5] sets the maximum number of points for each indicator. When the indicator reaches the recommended value, the value is 0. The HBS refers to the absolute value of the sum of the positive scores in all indicators; it reflects the degree of excessive intake in the diet and the score range is 0–32. The LBS refers to the absolute value of the sum of the negative scores in all indicators, and the score range is 0–54. Diet Quality Distance (DQD) refers to adding the absolute value of each index score to comprehensively reflect the problems in a specific diet, with a score ranging from 0 to 72.

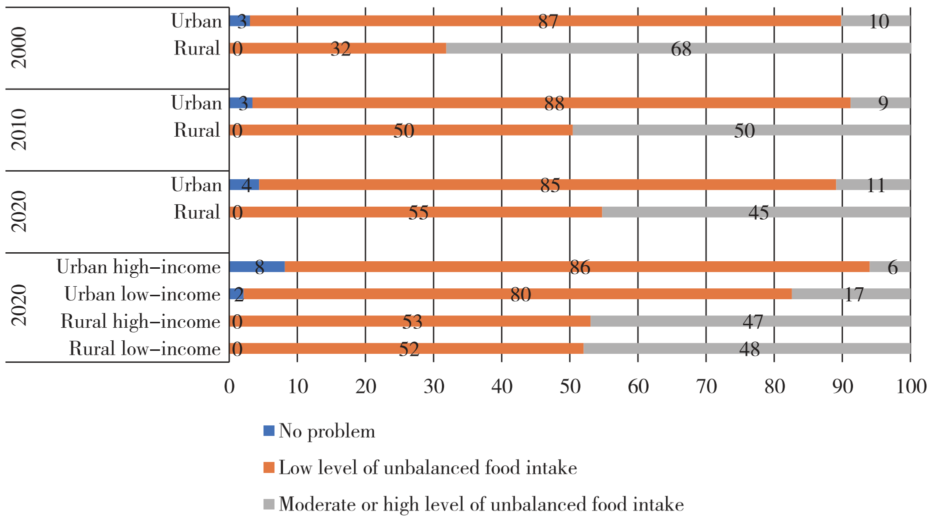
As shown by Figures 2-4 and 2-5,[6] the dietary quality of China's urban and rural populations has improved in the past two decades; however, the problems of under- and overconsumption coexist and there is a gap between the dietary quality of urban and rural populations. The dietary balance of urban and rural populations has improved and the proportion of rural residents with a high degree of imbalance in dietary

[5]Limited by the urban household survey data of the National Bureau of Statistics and food consumption data from the Fixed Observation Points in Rural Areas, the food types included in the DBI-16 indicator in this study are cereals and tubers, vegetables, fruit, dairy, livestock and poultry, aquatic products, eggs, and alcoholic beverages; it also includes edible oils that do not contain soybeans, salt, or added sugar. The score range and appropriate interval of each indicator are adjusted accordingly.

[6]In this study, the energy intake level of the converted standard person was 2,250 kcal (the standard of light physical labor for men aged 18–50 years). Each individual food group is scored to generate DBI-16 indicators.

quality has dropped from 68% in 2000 to 45% in 2020. The insufficient intake of urban and rural populations has been alleviated to a certain extent, with a more rapid improvement among urban residents. Insufficient intake at medium and high socioeconomic levels dropped from 20% in 2000 to 9% in 2020 and the proportion of rural residents whose dietary intake was insufficient dropped from 32% to 10%. The excessive food intake of urban and rural populations is at the same time becoming increasingly serious. The proportion of people whose diet was moderately or highly excessive increased from 10% in 2000 to 23% in 2020. There were also some differences in the dietary quality of urban and rural high- and low-income residents: in general, the dietary quality and sufficiency of intake of urban and rural high-income residents is better than that of the low-income group, however more attention needs to be paid to the dietary quality of rural low-income residents. The

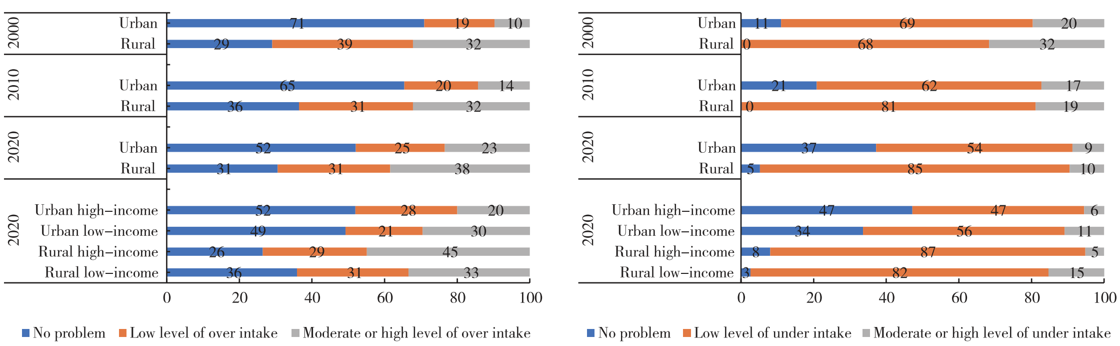
Figure 2-4 Distribution of Balanced Dietary Structure of Chinese People by Rural and Urban and by Income



Source: Urban data is from the National Bureau of Statistics of the Urban Household Survey; rural data is from Fixed Observation Points in Rural Areas; the 2020 data is calculated based on 2015 data and food consumption data from the National Bureau of Statistics.

Note: Urban and rural populations were divided into five equal parts according to disposable income, and the lowest-income group and the highest-income group were selected for the analysis.

Figure 2-5 Distribution of Underconsumption and Overconsumption of Chinese People by Rural and Urban and by Income



Source: Urban data is from the National Bureau of Statistics of the Urban Household Survey; rural data is from Fixed Observation Points in Rural Areas; the 2020 data is calculated based on 2015 data and food consumption data from the National Bureau of Statistics.

Note: Urban and rural populations were divided into five equal parts according to disposable income, and the lowest-income group and the highest-income group were selected for the analysis.

proportion of rural low-income people who experience a moderate or high level of dietary imbalance is 48% and the proportion of people whose intake is moderately or highly insufficient is 15%; in both cases, these are at the lowest level among urban and rural income groups.

2.4 Simulation results analysis of nutrition and health support policy

2.4.1 Method

We use the China Agricultural University's Agrifood System (CAU-AFS) model. This is an interdisciplinary model that not only can predict future changes in agricultural and food systems, but also can be used for policy simulation analysis. It can simulate the combined impact of various policies and external shocks on the agricultural and food system, including the impacts on food security, economic efficiency, nutritional health, resources, and the environment (For further details, refer to the appendix). Currently, the base year for the CAU-AFS model is 2018. According to future population and labor force growth, urbanization rates, and technology progress (using 2018 as the base year), the situation in 2030 is projected recursively and is regarded as the business-as-usual (BAU) scenario.

2.4.2 Scenario design

According to the analysis in Section 2.3, the intake of fruit, vegetables, aquatic products, and dairy products of urban and rural populations in China is lower than the recommended value; particularly for rural low-income residents, the gap between actual diet intake and the recommended value is large. Four food categories, namely, fruit, vegetables, aquatic products, and milk, have therefore been selected in this section to investigate how to formulate agricultural policies that support the production and consumption of foods in these categories.

In terms of the supply side, the existing policies are support policies to enhance the production of nutritious and healthy food, including fruit, vegetables, aquatic products, and milk; they are aimed at increasing food supply, reducing prices, and promoting consumption. In this way, residents can obtain these food groups at lower prices, which increases the affordability of healthy and nutritious food and improves dietary structure and nutritional health. This section simulates two types of policies that support the production of nutritious and healthy food; one increases producer subsidies for fruit, aquatic products, and milk and the other increases investment in science and technology. In the short term, the extension and application of technology should be accelerated. Vigorous promotion of organic fertilizer technology, for example, would increase fruit yields. In the long run, increasing investment in science and technology is necessary in order to break through bottlenecks, improve food productivity, and reduce food loss and waste. Fruit, vegetables, aquatic products, and milk are fresh agricultural products; they easily rot and deteriorate, are difficult to store, and have a high loss rate. According to estimates, the total losses of vegetables and fruit from all supply chain stages amount to 27.7% and 13.2% of total production, respectively (Lu et al., 2022). In order to reduce storage costs and losses and improve the capacity of food supply, it is necessary to increase investment in science and technology research that focuses on cold chain transportation technology of fresh agricultural products.

Based on the values recommended by the Chinese Dietary Guidelines 2016 and current food prices, the average per person per day cost of a nutritionally adequate diet is about CNY 11 (US$ 1.6). [7] Comparing current food expenditures and the cost of a nutritionally adequate diet for Chinese urban and rural populations, the average annual food budget of most Chinese is higher than the cost of the recommended healthy diet. This finding indicates that, with the exception of the rural low-income group, the recommended nutritionally adequate diet is affordable for most Chinese. In this section, we investigate a scenario in which the income subsidy of low-income residents is raised so that their income, purchasing power, and consumption level can be enhanced and their diet quality ultimately improved.

A healthy diet is key to improving nutrition and diet quality and decreasing the prevalence and mortality

[7] According to the recommended values of Chinese Dietary Guidelines 2016 and the edible proportion of various foods, the purchase amount corresponding to the recommended amount is inversely converted and then multiplied by the food price.

of diet-related diseases (Sheng et al., 2021). Thus, to strengthen public awareness, guidance, and intervention for a nutritious and healthy diet, it is necessary to construct a food education system, improve the current lack of knowledge about healthy diets, and promote a gradual transition to a nutritious and healthy diet. In this way, diet-related diseases can be prevented and the goals of health and longevity can be achieved (China Agricultural University et al., 2021).

We present four scenarios to BAU. In Scenario 1, producer subsidies for fruit, aquatic products, and milk are increased (Producer Subsidy); in Scenario 2, income subsidies are provided to rural low-income groups to improve their purchasing power of nutritious and healthy food (Income Transfer); in Scenario 3, organic fertilizer is applied to fruit, improving the yield (Tech Extension); and in Scenario 4, there is increased investment in science and technology research into fresh agricultural produce, focusing on supporting research to break through relevant technical problems of keeping produce cold, reducing losses and waste in storage and transportation, and improving supply capacity (Tech Investment). Considering the uncertainties embedded in the implementation of these policies, the effect of high-, medium-, and low-level applications of these scenarios is shown in Table 2-1.

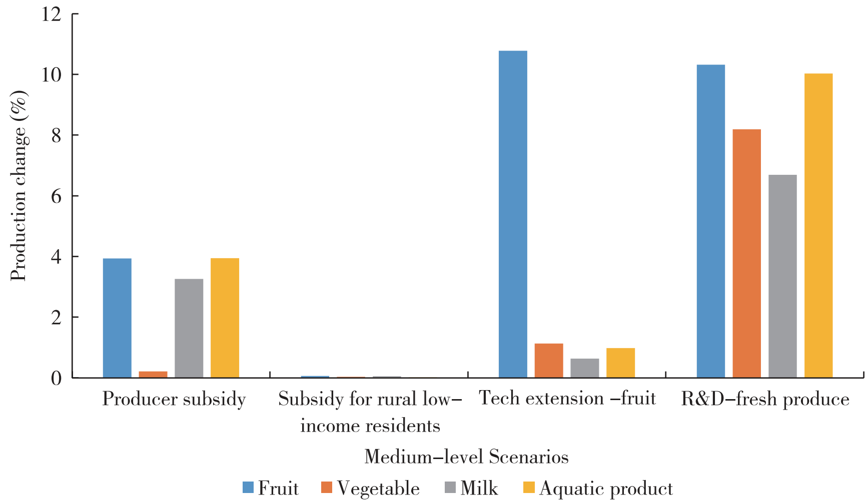
Table 2-1 Scenarios for Improving Diet Quality of Chinese People

Scenarios	Medium scenario	Low scenario	High scenario
Producer Subsidy	Subsidy is provided to producers in terms of fruit, milk, and aquatic products; it is calculated at 10% of the total output value; in 2018, the subsidy is around CNY 273.9 (US$ 40.9) billion	Subsidy is provided to producers in terms of fruit, milk, and aquatic products; it is calculated at 5% of the total output value; in 2018, the subsidy is around CNY 137 (US$ 20.4) billion	Subsidy is provided to producers in terms of fruit, milk, and aquatic products; it is calculated at 15% of the total output value; in 2018, the subsidy is around CNY 410.9 (US$ 61.3) billion
Income Transfer for rural low-income residents	Income transfer is provided to 20% of low-income rural residents; this would increase by about CNY 100 (US$ 14.9) billion per year until 2030	Income transfer is provided to 20% of low-income rural residents; this would increase by about CNY 80 (US$ 11.9) billion per year until 2030	Income transfer is provided to 20% of low-income rural residents; this would increase by about CNY 120 (US$ 17.9) billion per year until 2030
Tech Extension—fruit	Organic fertilizer is applied to fruit to increase yield; 5 metric tons/hectare (mt/ha) of organic fertilizer is applied, at CNY 600 (US$ 89.6)/mt; the subsidy rate is 50%, the coverage rate is 50%, and the investment is about CNY 8.9 (US$ 1.3) billion; this would increase yield by 10%	Same assumptions as medium-level scenarios; yield of fruit would increase by 5%	Same assumptions as medium-level scenarios, the yield of fruit would increase by 15%
Tech Investment—fresh produce	Investment in science and technology for fresh agricultural products is increased by CNY 30 (US$ 4.5) billion per year. Until 2030, the supply of fruit, vegetables, aquatic products, and milk will be increased and food loss and waste will be reduced by 10%	Same assumptions as medium-level scenarios; until 2030, the supply of fruit, vegetables, aquatic products, and milk will be increased and food loss and waste will be reduced by 5%	Same assumptions as medium-level scenarios; until 2030, the supply of fruit, vegetables, aquatic products, and milk will be increased and food loss and waste will be reduced by 15%

2.4.3 Analysis of simulation results

In this section, we analyze the impact of the medium-level version of each scenario on food supply and consumption by 2030. First, increasing producer subsidies, investment, and public awareness of science and technology in important agricultural products that are insufficiently consumed, such as, fruit, vegetables, aquatic products, and milk, can increase the production of these foods to varying extents. As Figure 2.6 shows, until 2030—compared with the benchmark—higher producer subsidies can increase the production of fruit, milk, and aquatic products by 4.0%, 3.3%, and 4.0%, respectively, and promoting the use of organic fertilizer for fruit production can increase yield by 10.8%. Investment in science and technology research into fresh agricultural produce, reduction of food loss and waste, and improved productivity can increase the production of fruit, vegetables, aquatic products, and milk by 10.3%, 8.2%, 10.0%, and 6.7%, respectively (Figure 2-6).

Figure 2-6 Impact of Different Scenarios on the Production of Fruit, Vegetables, Milk, and Aquatic Products–2030 Compared with the Baseline



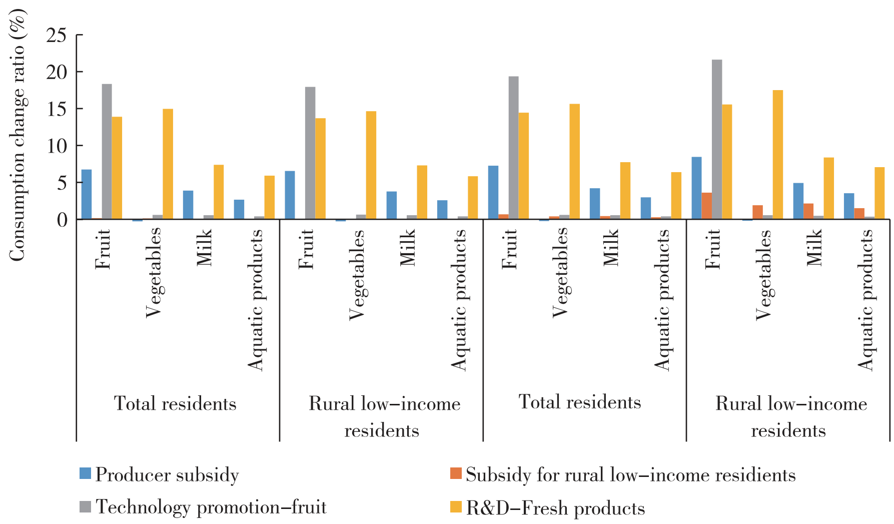
Source: Results are from the CAU-AFS model.

After production rises, prices drop and consumption increases. In the Producer Subsidy scenario, the consumption of fruit, milk, and aquatic products by urban and rural populations increases by 6.7%, 3.9%, and 2.7%, respectively. Among these, the consumption of fruit, milk, and aquatic products by rural low-income residents increases most significantly, going up by 8.4%, 4.9%, and 3.6%, respectively. In the Tech Extension scenario, the increase in fruit production results in a 20.7% decline in prices and an 18.3% rise in fruit consumption by urban and rural populations. In the Tech Investment scenario, increasing investment in science and technology research into fresh agricultural produce reduces food loss and waste; productivity is also increased and the price of fruit and vegetables is reduced by 13.8% and 32.0%, respectively; consumption increases by 13.0% and 19.6%, respectively.

In the Income Transfer scenario aimed at rural low-income residents, when their income increases their food affordability also increases; the consumption of nutritious foods such as fruit, vegetables, aquatic products, and milk increases by 8.4%, 3.6%, and 4.9%, respectively (Figure 2-7). Owing to the low demand income elasticity of food consumption, however, the performance of influencing food consumption by increasing income is not ideal; therefore, when providing income transfers to the low-income group we consider that issuing food stamps would increase the consumption of certain insufficient foods and therefore improve diet quality.

From the perspective of economic efficiency of investment, the cost of investment in science and technology research and technology extension is small and the return on investment is high. In the Tech Extension scenario, the return on investment of CNY 1 (US$ 0.1) of agricultural, agrifood system, or national economic GDP is higher, that is, CNY 9.4, 13.2, and 21.1 (US$ 1.4, 2.0, and 3.1), respectively. This means that every additional investment of CNY 1 (US$ 0.1) can

Figure 2-7 Impact of Different Scenarios on the Consumption of Fruit, Vegetables, Milk, and Aquatic Products–2030 Compared with the Baseline



Source: Results are from the CAU-AFS model.

drive the agricultural GDP to increase by CNY 9.4 (US$ 1.4), and through the pull of the industrial chain and the flow of the labor force to non-agricultural industries, the GDP of the whole agricultural and food system and the GDP of the national economy will increase by CNY 13.2 (US$ 2.0) and CNY 21.1 (US$ 3.1), respectively. The development period needed for science and technology is long, but the long-term income is promising. The return on investment of CNY 1 (US$ 0.1) of agricultural, agrifood system, and national economy GDP is CNY 9.6, 15.7, and 23.2 (US$ 1.4, 2.3, and 3.5), respectively (Table 2-2). Given the uncertainty of the impact of technology extension and investment in science and technology, in the high-, and low-level scenarios the rate of return on investment also exhibits some uncertainty. Overall, the returns on investment are high at the high, medium, and low levels of the Tech Investment scenarios. The return on investment of agricultural GDP for the Tech Extension scenario ranges from CNY 4 (US$ 0.6) to 14 (US$ 2.1), and that of the Tech Investment scenario ranges from CNY 5 (US$ 0.7) to CNY 14 (US$ 2.1).

The macro simulation results of the CAU-AFS model are further linked to the micro survey data (National Bureau of Statistics urban household survey and Fixed Observation Points in Rural Areas dataset). They are used to simulate the impact differences of various support policies on different micro individuals and to analyze consumption changes within the different groups, quantifying the impact of various support policies on diet quality (for specific results, refer to Figure 2-8).

Table 2.2 Return on Investment for Different Scenarios

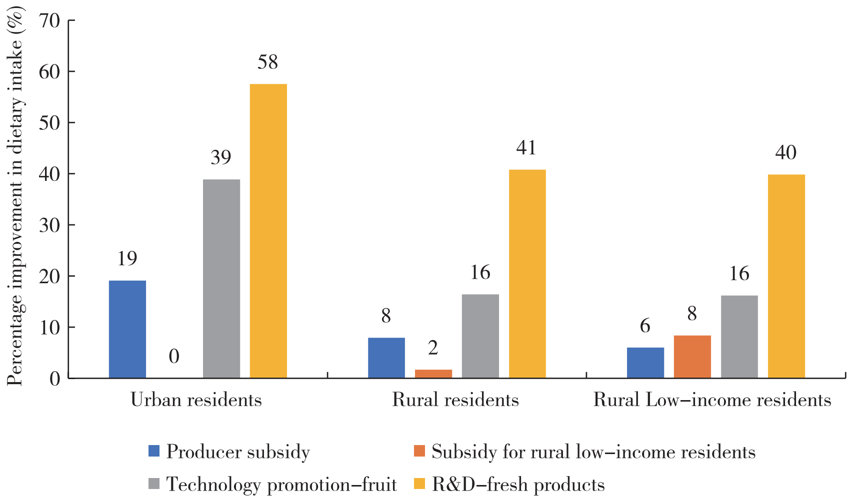
Scenario	Low			Medium			High		
	Total GDP	Agrifood system	Agric-ulture	Total GDP	Agrifood system	Agric-ulture	Total GDP	Agrifood system	Agric-ulture
Tech Extension–fruit	10.6	6.7	4.7	21.1	13.2	9.4	31.1	19.6	14.2
Tech Investment–fresh produce	12.4	8.4	5.1	23.2	15.7	9.6	32.8	22.5	13.9

Source: Results are from the CAU-AFS model.

The increasing consumption of fresh agricultural produce results in the improvement of the insufficient intake situation of these food groups and accordingly the improvement of diet quality. The performance of the Tech Investment scenario is particularly remarkable. The base amount of nutritious and healthy food consumption is small for rural residents and thus, even if the increased rate of rural consumption of nutritious and healthy food is greater than that of urban residents, the change in absolute amount is still small. From the perspective of the DBI-16 score, the improvement degree of dietary quality of rural residents will be lower than that of urban residents. In the Producer Subsidy scenario, the insufficient intake of nutritious and healthy food for urban and rural populations is improved by 19% and 8%, respectively, and the proportions of urban and rural populations with medium- and high-level dietary imbalance are reduced by 5% and 1%, respectively. In the Income Transfer scenario, 8% of rural low-income residents improve their intake of nutritious and healthy food; however, owing to the seriously insufficient intake of fruit, aquatic products, and dairy products, it is still difficult for these policies to achieve a balanced diet, and dietary quality has thus not been fundamentally changed. In the Tech Extension scenario, 39% of urban residents and 16% of rural residents improve their intake of nutritious and healthy food. In the Tech Investment scenario, 58% of urban residents and 41% of rural residents improve their intake of nutritious and healthy food (Figure 2-8).

Considering the uncertainty of subsidy intensity, in the high- and low-level scenarios there is also

Figure 2-8 Improvement of Different Scenarios on the Dietary Intake of Chinese People–2030 Compared with the Baseline



Source: Results are from the CAU-AFS model.

uncertainty in the technology promotion and investment effect of science and technology, food production, and consumption (for more details, see Table A2-1 in the Appendix). In the Producer Subsidy scenario, the production of milk and aquatic products fluctuates by 2 percentage points based on the medium-level scenario; accordingly, consumption fluctuates by 1–3 percentage points. In the Tech Extension scenario, fruit production fluctuates by 6 percentage points based on the medium-level scenario, and fruit consumption fluctuates by 10 percentage points. In the Tech Investment scenario, the production of fruit, vegetables, milk, and aquatic products fluctuates by 3–5 percentage points based on the medium-level scenario, and consumption also fluctuates by 3–8 percentage points. Overall, in the high-, medium- and low-level scenarios, tech promotion, and tech investment in science and technology significantly improve diet quality (see Table A2-2 in the Appendix). In the Tech Extension scenario, the inadequate dietary intake of 20% to 56% of urban residents and 8% to 24% of rural residents is improved (Table A2-2 in the Appendix). In the Tech Investment scenario, 34% to 72%

of urban residents and 24% to 54% of rural residents improve their intake of nutritious and healthy food.

2.4.4 Health benefits of dietary quality improvement

According to estimates by the National Institute for Nutrition and Health of the China Center for Disease Control and Prevention, insufficient intake of fruit and vegetables in 2010 accounted for 11.5% and 7.3% of the deaths attributed to cardiovascular diseases among Chinese residents (He, et al., 2019). To further explore the health benefits resulting from dietary quality improvement, the 2019 global burden of disease (GBD) database is used to analyze the prevalence of diet-related diseases and the resulting disability-adjusted life years (DALYs) and thus the disease cost. Simultaneously, by doing a literature search, we compare the impact of food intake changes on disease risk.

As shown in Tables 2-3 and 2-4, a 100g/day intake of red meat increases the prevalence of cardiovascular disease, stroke, colorectal cancer, and Type-2 diabetes by 15%, 12%, 12%, and 17% respectively, and the corresponding losses caused by DALYs will increase by CNY 950.2 (US$ 141.8) billion, CNY 1,403.8 (US$ 209.5) billion, CNY 51.50 (US$ 7.7) billion, and CNY 112.5 (US$ 16.8) billion, respectively. If the daily intake of red meat increases by more than 100g, the cumulative cost will increase by CNY 2,518 (US$ 375.8) billion. On the other hand, increasing vegetable intake by 100 g/day will reduce the mortality caused by cardiovascular disease by 16% and will reduce the loss caused by DALYs by CNY 1,013.5 (US$ 151.3) billion. With a 100 g/day increase of fruit intake, the mortality caused by cardiovascular disease and stroke drops by 5% and 23%, respectively, and the loss caused by DALYs decreases by CNY 316.7 (US$ 47.3) billion and CNY 1,379.3 (US$ 205.9) billion, respectively. If the intake of fruit is increased by a further 100 g/day, the cumulative loss can be reduced by another CNY 1,696.0 (US$ 253.1) billion. If the intake of aquatic products increases by 15 g/day, the mortality caused by cardiovascular diseases decreases by 6% and the loss caused by DALYs decreases by CNY 380.1 (US$ 56.7) billion. If calcium intake increases by 0.3 g/day, the prevalence of colorectal cancer decreases by 8% and the loss caused by DALYs decreases by CNY 34.4 (US$ 5.1) billion.

In the Tech Investment scenario, which has the greatest impact on the increased intake of fruit, vegetables, aquatic products, and milk, the intake of items in these four categories increases by 13.9%, 15.0%, 7.4%, and 5.9% respectively. This may contribute to a reduction in the prevalence and mortality of cardiovascular disease, stroke, and colorectal cancer, and to corresponding decreases in the loss caused by DALYs.

Table 2-3 Prevalence or Mortality Risk of Various Diseases and the Corresponding Costs

Indicators	Disease	Prevalence/mortality (‰)	The DALYs of 1% prevalence/mortality (100 million year)	The cost of 1% prevalence/mortality (CNY 10 billion) *
Mortality	Colorectal cancer	0.18	3.46	2,422.23
	Cardiovascular	3.18	2.84	1,989.60
	Stroke	1.46	5.88	4,119.25
	Type-2 diabetes	0.12	7.97	5,587.65
Prevalence	Colorectal cancer	2.26	0.27	189.70
	Cardiovascular	83.09	0.11	76.23
	Stroke	19.69	0.85	594.22
	Type-2 diabetes	63.68	0.01	10.14

Source: Mortality, prevalence, and disability-adjusted life years (DALYs) data are from 2019 Global Burden of Disease (GBD) data (Global Burden of Disease Results, 2019); the estimated value of per capita GDP comes from the National Bureau of Statistics.

Note: This is calculated by multiplying DALYs corresponding to 1% prevalence/mortality by China's per capita GDP in 2019.

Table 2-4 Relationship Between food Intake and Disease Risk, and its Cost–benefit

Indicator	Disease	Food category	Increase amount (g/day)	Cost (CNY billion) [a]	Decrease or increase preva-lence/mor-tality (%)	DALYs change income (CNY 10 billion)	Calculation reference (sources)
Mortality	Cardiovascular	Aquatic products	15	0.35	-6	38.01	Bechthold et al. (2019)
	Cardiovascular	Fruit	100	0.66	-5	31.67	Bechthold et al. (2019)
	Stroke		100	0.66	-23	137.93	Schwingshackl et al. (2016)
	Cardiovascular	Vegetables	100	0.47	-16	101.35	Schwingshackl et al. (2016)
Preva-lence	Cardiovascular	Red meat	100	4.1.5	15	-95.02	Zheng et al. (2012)
	Stroke		100	4.15	12	-140.38	Aune et al. (2017)
	Colorectal cancer		100	4.15	12	-5.15	Aune et al. (2017)
	Type-2 diabetes		100	4.15	17	-11.25	Aune et al. (2017)
	Colorectal cancer	Calcium[b]	0.3	2.00	-8	3.44	Keum et al. (2014)

Source: The increase amount of food category and decrease or increase prevalence/mortality is from the literature; and disability-adjusted life years (DALYs) data are from 2019 Global Burden of Disease (GBD) data (Global Burden of Disease Results, 2019).

Note: a) The cost is calculated by multiplying the added quantity by the price of food, and then by the total population of China at the end of 2019; b) Each 100 ml of milk contains about 110 mg of calcium, and the costs and benefits are calculated based on milk consumption; DALY = disability-adjusted life years.

2.5 Conclusion and recommendation

Agrifood systems in China and around the world are currently plagued by numerous threats and challenges, including those related to the nutrition and health of their populations. In the past two decades, the dietary quality and nutrition of Chinese people have improved, but challenges remain with regard to dietary structure; these include overconsumption of highly processed foods, cereals, edible oil, and red meat, as well as insufficient intake of fruits, vegetables, aquatic products, and dairy products. Serious deficiencies of some nutrients are also still being observed. Based on this, this chapter explores the feasibility of various support policies to optimize the dietary structure and nutritional health of residents. It uses the CAU-AFS model to analyze and simulate the effects of different support policies from both the supply and demand sides. Based on the simulation results, the following suggestions are proposed.

First, China must improve the supply capacity of nutritious and healthy food, adjust and optimize the food production structure, and reduce the price of nutritious and healthy food, with the aim of forever improving residents' food consumption structure and their dietary quality. Science and technology support policies are more effective than producer subsidies. It is therefore essential to transform agricultural science and technology support policies, increase R&D investment, improve the production of nutritious and healthy food, reduce the loss of fresh agricultural produce, and enhance the supply capacity of nutritious and healthy food.

Second, it is imperative to adopt specific support policies for low-income groups—especially the consumption support of nutritious and healthy food—so as to improve their access to nutritious food and improve their dietary quality. Production-oriented support policies are mostly aimed at improving supply of nutritious foods. Low-income people, however, have limited purchasing power, and they can thus benefit only via a decrease in food prices; therefore, starting from the consumption side, low-income rural residents should be given income transfers or food vouchers to narrow the gap in dietary quality between urban and rural populations, improve health levels, and significantly improve health equity.

Finally, it is difficult to completely change food consumption behavior by economic measures alone. In the long run, nutritious and healthy food consumption intervention is needed to guide residents to form balanced food consumption concepts, change food consumption behavior, and optimize their dietary structure. Strengthening dietary guidance and nutrition education is a fundamental step in reinforcing food nutrition. China needs to combine guidance with nutrition interventions. It should increase public awareness of good nutrition, discourage consumption of unhealthy foods, encourage a scientific and balanced diet, prevent and control nutrition-related diseases, and improve food and nutrition structure.

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Appendix

Table A2-1 Impacts of High-and Low-scenarios on Fruit, Vegetable, Milk, and Aquatic Product Production and Consumption of Chinese People (%)

		Producer Subsidy	Subsidy for rural low-income residents	Tech Extension—Fruit	Tech Investment—Fresh Products		Producer Subsidy	Subsidy For rural low-income residents	Technology Extension—Fruit	Tech Investment—fresh Products
	Low scenario	Yield variation				High scenario	Yield variation			
Fruit		2.0	0.1	5.3	5.4		5.8	0.1	16.6	15.1
Vegetables		0.1	0.0	0.6	5.0		0.3	0.0	1.6	15.3
Milk		1.7	0.0	0.3	3.6		4.9	0.1	0.9	10.7
Aquatic products		2.0	0.0	0.5	5.2		5.9	0.0	1.4	15.0
		Consumption of urban and rural populations					Consumption of urban and rural populations			
Fruit		3.4	0.1	8.8	6.7		10.1	0.2	28.8	19.9
Vegetables		-0.1	0.1	0.3	9.2		-0.4	0.1	0.9	28.9
Milk		1.9	0.1	0.3	3.9		5.8	0.1	0.8	12.04
Aquatic products		1.3	0.0	0.2	3.0		3.98	0.04	0.56	8.83
		Consumption of rural low-income residents					Consumption of rural low-income residents			
Fruit		4.2	2.7	10.3	7.5		12.7	4.0	33.9	22.1
Vegetables		-0.1	1.4	0.3	10.8		-0.3	2.1	0.8	33.8
Milk		2.5	1.6	0.3	4.4		7.4	2.4	0.7	13.6
Aquatic products		1.8	1.1	0.2	3.5		5.3	1.7	0.5	10.5

Source: Results are from the CAU-AFS model.

Table A2-2 Impacts of High-and Low-scenarios on Diet Quality of Chinese People (%)

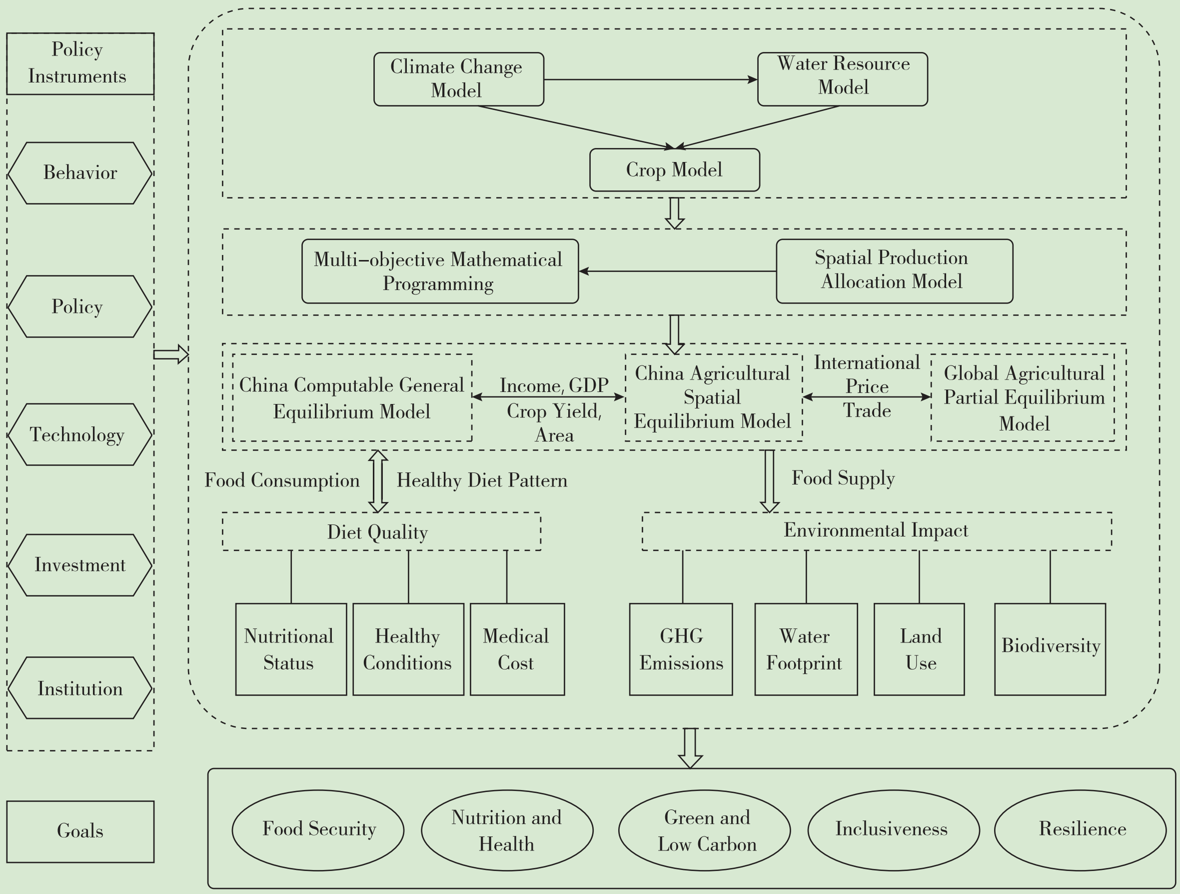
		Improvement proportion of inadequate intake (LBS)			
	Scenarios	Producer Subsidy	Subsidy for Low-income Rural Residents	Technology Extension–Fruit	Tech Investment–Fresh Products
Improvement proportion of urban residents	Low	10	0	20	34
	Medium	19	0	39	58
	High	28	0	56	74
Improvement proportion of rural residents	Low	4	1	8	24
	Medium	8	2	16	41
	High	11	2	24	56
Improvement proportion of rural low-income residents	Low	3	7	6	22
	Medium	6	8	16	40
	High	10	11	24	57

Source: Results are from the CAU-AFS model.

A Brief Introduction to the CAU Agrifood System Model

The agrifood system faces numerous challenges and must be transformed to achieve multiple goals, including better nutrition, improvement in health, protecting natural resources and environment and carbon emission reduction, and common prosperity and resilience. To provide technical support for policy analysis under these multifaceted objectives, China Agricultural University (CAU) is developing an Agrifood System Model (CAU-AFS Model), which is an interdisciplinary model combining factors relating to agriculture, food, nutrition, economics, and environment. The CAU-AFS model is based on two core models – the China Agricultural Spatial Equilibrium Model and the China Computable General Equilibrium Model (CGE), which are flexibly linked with other models in the fields of agricultural production, natural resources, nutrition, and health, such as the climate change model, the water resources model, the crop model, and the dietary model, etc. It can be used as a simulation platform for simulating and analyzing the multidimensional impacts of various policy changes and external shocks on the agrifood system, such as food security, economic efficiency, nutrition, health, and resources and environment. The CAU-AFS model can be used to investigate various major issues related to agrifood system transformation in the context of the multiple national development goals. The framework of the CAU-AFS model is depicted below, and the model will be constantly developed and Improved.

The Framework of the CAU Agrifood System Model (the CAU-AFS Model)



In this report, the China CGE model, nutrition and health module, and carbon emission module are mainly applied to simulate the impacts of various agricultural support policies on multiple goals of the agrifood system, including food security, economic efficiency, nutrition and health, protection of natural resources and environment and carbon emissions reduction. The CGE model is an economic system model. It describes the equilibrium state in all markets and establishes the linkages among different sectors, covering all aspects of production, consumption, and trade. Moreover, it presents the complex connections and interactions within the economic system. Therefore, the CGE model is widely employed in diverse research fields as an important policy analysis tool. The China CGE model is based on the RIAPA (Rural Investment and Policy Analysis) model developed by the International Food Policy Research Institute (IFPRI) using the most recent data from China. China's CGE model has in-depth details of agricultural sub-sectors and its value chain sectors, having the advantage of analyzing the interactions between the agrifood system and the national macro economy. The RIAPA model is developed specifically for analyzing the impact of rural investment and policy based on the CGE model. It also allows for simulating the public expenditure and economic growth as well as synergies between economic growth and other development outcomes. It is widely used to identify the priorities of agricultural R&D and extension, and various public investments and policies in a multi-goals context, such as the goals of poverty alleviation, employment, and dietary quality improvement.

1. Theoretical basis of China CGE model

The China CGE model is mainly based on the Walrasian general equilibrium theory and the neoclassical economics theory, using a set of linear and nonlinear equations, which reflects the activities, goods, factors, and institutions in the China Social Accounting Matrix (SAM). In the China CGE model, the production module consists of multi-level nested equations, and the factors of production include capital, land, and three types of labor with skills categorized as high, medium, and low. Additionally, there are imperfect substitution relationships among various factors of production and the value-added equations using the specification of Constant Elasticity Substitution (CES). The intermediate input function is composed of various intermediate inputs according to the fixed input-output coefficients using the Leontief function. Then, value-added and intermediate inputs determine the output of the product according to the form of the Leontief function. For international trade, considering the imperfect substitutability of domestic and international goods, the Armington specification (CES equation) is used to reflect the substitution relationship between domestic and imported goods. The lower value of Armington elasticity indicates a greater difference between domestic and imported products. The Constant Elasticity of Transformation (CET) function is used for reflecting the difference between domestic sales and exported products. The main sources of household income are factor income, government transfers, and remittances. While part of the income is spent on consumption, the rest goes into savings. The household consumption is derived from the Linear Expenditure System (LES) using the Stone-Geary utility function under the constraints of income budgetary. Government revenues come from a variety of taxes and are used to purchase goods and services, make household transfers, and provide foreign aid. The difference between government revenue and expenditure is known as government savings or fiscal deficit.

2. The construction of the China Social Accounting Matrix (SAM)

This study uses the latest 2018 China Input-Output Tables covering 153 sectors and the cost-benefit data of various agricultural products to construct the Social Accounting Matrix (SAM). The China SAM contains details of sectors of agriculture and its processing and intermediate inputs, and can fully reflect the interconnections of the entire value chains. It comprises a total of 88 sectors, including 23 agricultural sub-sectors, 15 food processing sectors and agricultural processing sectors, 2 intermediate input sectors of chemical fertilizers and pesticides, and 48 industries and services sectors. Agricultural sub-sectors include 14 crops (rice, wheat, corn, other grains, beans, peanuts, rapeseed, cotton, sugarcane, sugar beet, fruits, vegetables, raw tobacco, and other crops) and 6 animal husbandry sectors (pork, beef, mutton, poultry, eggs, and milk), as well forestry, aquatic products, and agricultural services. In addition, the households are divided into 40 groups based on their location (urban or rural) and income level, which can be used to analyze different impacts on different household groups. The main production factors are labor, capital, and land. Labors are classified as high, medium, and low-skilled depending on their education levels.

3. The assumptions in the China CGE model

In the China CGE model, the factors of labor, capital, and land are assumed to be fully employed or utilized. Wage rates, land rental prices, and capital returns are all endogenous variables that will change as the economy grows. Although the land and labor factors are assumed to be transferable among sectors, the substitution effects of different factors are limited. In macro closure, the term investment-savings equilibrium refers to a situation in which investment equals savings. The sum of private savings, government savings, and foreign savings equals total savings. The sum of investment and inventories is referred to as total investment. The macro closure rule for investment savings assumes that savings drive investment. In the government accounts, if public spending increases, either government savings fall or the fiscal deficits rise. The exchange rate is assumed to be endogenous in the balance of payments account, and international market outflows are regulated by the changes in the exchange rate.

4. Incorporating the nutrition and diet module

Linkages were established between the China CGE model and the micro household survey data to further explore the impacts of various policies on the nutrient intake and diet structure. By linking the percentage changes of various food consumption of urban and rural residents in each income group from the results of the China CGE model with the food consumption by income group from the household survey data, a number of indicators under the effects of various scenarios were re-estimated. The Chinese Dietary Balance Index (DBI), high bound score (HBS) and low bound score (LBS), and the dietary quality distance (DQD) indicators are among these indicators and their changes reflect the effects of various policies on the dietary quality of different household groups.

5. Incorporating the GHG emissions module

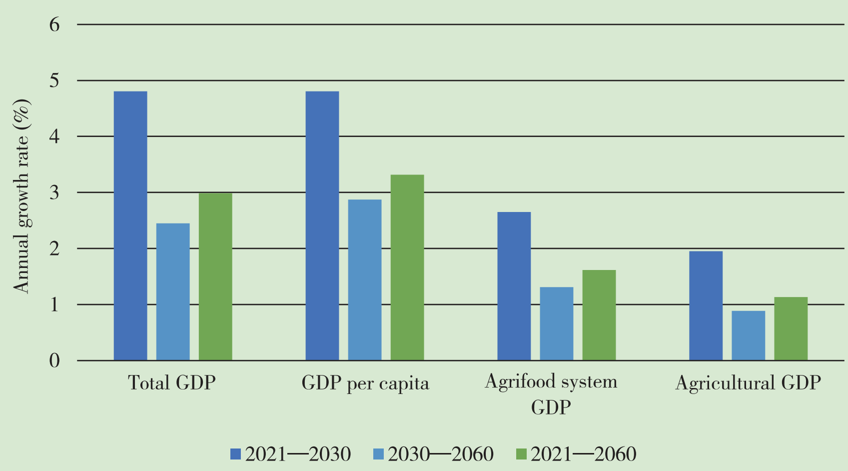
The China CGE model encompasses the entire agrifood system, including agriculture, agricultural and food processing, as well as intermediate inputs such as chemical fertilizers and pesticide sectors, and agriculture and food-related services. Therefore, the total greenhouse gas (GHG) emissions from the agrifood system can be calculated using the carbon emission coefficients of various agricultural products, agricultural and food processing, and intermediate inputs. The purpose of adding this module is to evaluate the impacts of policy changes on emissions from the agrifood system. Among them, crop emissions mainly include emissions from crop residue, straw burning, fertilizer use, and rice field cultivation. It is based on the calculation method of FAO, which incorporates the estimated emission structure from fertilizer use by various crops, as well as the fertilizer use per unit area of various crops from the China Agricultural Products Cost-Benefit Compilation of Information and the area of various crops from the China Statistical Yearbook. The emissions from fertilizer use by crop were estimated using FAO 's total emissions from fertilizer use and the emission coefficient of fertilizer use per unit of crop area. However, the impact of land-use change on GHG emissions was not considered in this study. The emission factors per unit of livestock production are obtained from the FAO database (FAOSTAT), which mainly includes animal enteric fermentation and animal manure management.

6. The baseline of CAU-AFS model

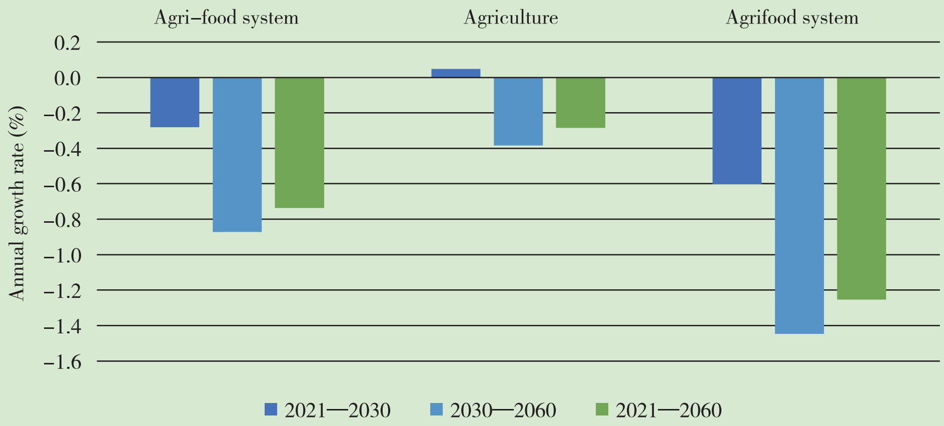
The base year is 2018. In the base year, the GDP shares of agriculture and agri-food systems were 7.4% and 15.1%, and the employment shares were 25.8% and 31.2%, respectively. The recursive dynamics are projected to 2030 and 2060 in the baseline scenario, based on future population and labor growth, urbanization rates, and technological progress. As a benchmark scenario without policy and external shocks, the future national economic development, agricultural production, household food consumption, and carbon emissions of the agrifood system are projected based on technological progress, population and labor growth, and other factors according to the business as usual. According to the population growth projections from the Development Research Center of the State Council (DRC), the baseline scenario assumes that the population size peaks in 2022 and then gradually decreases to 1.342 billion and 1.204 billion in 2035 and 2050, respectively, and the population size in 2050–2060 are projected with reference to the population growth rate from the medium scenario of the United Nations population projection, and the total population in 2060 is estimated to be about 1.144 billion. Under the baseline scenario, China's total GDP will continue to grow, but at a slower growth rate over time, with the agricultural and agrifood system GDP growing at a slower rate than the overall national economy. As the total population declines slowly, China's GDP per capita would grow slightly faster than the total GDP. The average annual GDP growth rate will be around 3.0% between 2021 and 2060, 4.8% between 2021 and 2030, and down to 2.4% between 2030 and 2060. GDP per capita would grow at 3.3% from 2021 to 2060, which is almost the same as the GDP growth rate of 4.8% from 2021 to 2030, and 2.9% from 2030 to 2060. Agricultural GDP grows relatively slowly compared to total GDP, with growth rates of 1.6% for agricultural GDP and 1.1% for agrifood system GDP between 2021 and 2060, respectively.

Under the baseline, the emissions from China's agri-food system show a decreasing trend, mainly due to the decline of the emission factors, which was fueled by technological progress and increased energy use efficiency. It is assumed that future emission factors will decrease by 20% cumulatively by 2060 when compared to 2018. Taking into account the future technological progress, the emission factors of livestock products are assumed to face a 20% cumulative decrease by 2060, the feed conversion rate is assumed to increase by 20% until 2060, implying that the intermediate input demand for feed grain from livestock sectors will decrease accordingly. On the other hand, as the population reaches its peak and the food consumption structure becomes relatively stable, the production of agricultural products generally tends to increase and then decrease. Between 2021 and 2030, the emissions from the agrifood system will decrease by 0.3% per year on average, while the emissions from the agrifood system would decrease by 0.9% per year on average. Among them, the emissions from agriculture change slowly, with an average annual increase of 0.05% from 2021 to 2030, and an average annual decrease of 0.4% from 2030 to 2060 due to the improvement of living standards and the increase in residents' consumption of livestock products. The energy carbon emissions of the agrifood system decline at a faster rate, with an average annual decrease of 1.3% from 2021 to 2060.

The GDP Growth in China Under the Baseline



The Emission of Agrifood Systems Growth in China Under the Baseline



7. Simulation of agricultural support policy

An interdisciplinary integration model of agriculture, food, the economy, nutritional health, resources, and the environment is developed based on the China CGE model and the nutritional diet and carbon emission modules, which can be used to simulate the impacts on food security, economic benefits, resources, the environment, and nutritional health of different policy scenarios. This provides the government with scientific evidence of trade-offs and synergies between multiple goals in decision-making. Agricultural support policies mainly include domestic support policy, investment, trade, etc. Policies such as agricultural producer subsidies and residential income subsidies can directly set the variables in the CGE model. For example, when simulating the effects of producer subsidy and residential income subsidies, the parameters of the activity tax and household transfer from the government in the CGE model can be changed, and the model can then be re-solved, and the policy impacts can be calculated by comparing the simulation results to the benchmark. The relationships between agricultural public investment and sectoral productivity are primarily established using the results of relevant existing literature on agricultural public investment such as high-standard farmland construction, agricultural R&D and extension. The impacts of agricultural public investments on production, consumption, trade, and the national economy are simulated using the China CGE model through total factor productivity (TFP). In the CGE model, agricultural public investments are financed by government savings, ensuring that trade-offs with other public investments are taken into account. The agricultural public investment, the investment circle, and the lag time, as well as the coverage and adoption rates, are also considered in greater details, and the long-term expenditures and returns of public investment in agriculture are dynamically simulated by discounting all expenditures and returns over the simulation period to their present value and calculating the average rate of return on investment.

Chapter 3

Repositioning Agricultural Support Policies for Achieving China's 2060 Carbon Neutrality Goal

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Key Findings

● Since 2015, China has initiated the reform of agricultural support policies toward green development. This has included zero-growth for chemical fertilizers and pesticides, implementation of resource utilization of livestock and poultry manure, and ecological compensation. From 2015 to 2019, fertilizer use in China fell 10.3 percent, but the amount of fertilizer use per hectare is still 2.9 times the global average and 2.8 times that of the United States. China's 2060 goal of carbon neutrality, however, has set new requirements for agricultural support policies.

● Repositioning agricultural support policies to promote the application of green and low-carbon technologies can achieve win–win results in food security and in reductions of greenhouse gas (GHG) emissions within agrifood systems. It can also yield high economic returns and environmental benefits. Green technologies can include organic–inorganic compound fertilizers, alternate wetting and drying technology for rice crops, and feed supplements technology.

● While ensuring food security remains the nation's top priority, the adoption of agricultural green and low-carbon technologies can reduce GHG emissions from agrifood systems by 150 to 240 million metric tons (Mmt) of carbon dioxide equivalent (CO_2eq) by 2030, accounting for 11.8 to 18.6 percent of GHG emissions from agrifood systems. By 2060, GHG emissions from agrifood systems can be reduced by 290 to 420 Mmt CO_2eq, accounting for 29.1 to 42.4 percent of GHG emissions from agrifood systems.

Policy Recommendations

- Agricultural support policies and agricultural science and technology investments should be repositioned to promote the transition to green, low-carbon, and sustainable agrifood systems.
- Agricultural support policies should stimulate research into, and extension for, win–win agricultural production technologies that have high-efficiency, green, and low-carbon characteristics, such as new type of fertilizers and equipment. Meanwhile, new institutions, organizations, and agencies that provide agricultural extension services should be encouraged to improve incentives for farmers' participation.
- To attract businesses, social service organizations, and farmers to participate in GHG emissions reduction actions and share its benefits, the government should promote the carbon market mechanism for agrifood systems and the mechanism for distributing the benefits of GHG emissions reduction.

3.1 Introduction

Agrifood systems are both a contributor to greenhouse gas (GHG) emissions and an important sector for achieving China's 2060 carbon neutrality goal and mitigating climate change. Rising global temperatures and frequent extreme weather have greatly weakened agricultural production capacity (IPCC, 2021). The need to mitigate climate change by reducing GHG emissions has global consensus. In 2020, the Chinese government made an important commitment toward peaking its carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060. Under China's 2060 carbon neutrality goal, the contribution of agrifood systems to GHG emissions reduction cannot be ignored. According to estimates by the Academy of Global Food Economics and Policy (AGFEP) at China Agricultural University (AGFEP, 2021), GHG emissions from agrifood systems reached 1.09 billion metric tons (t) of CO_2eq in 2018, accounting for 8.2 percent of total national GHG emissions.[1] While ensuring food security as the top national priority, the combined measures can reduce GHG emissions by 47 percent by 2060, compared to 2020 levels; these measures include improving agricultural technologies, reducing food loss and waste, and shifting dietary patterns. When coupled with the carbon sequestration of land use, land-use change and forestry (LULUCF), agrifood systems can contribute significantly to achieving carbon neutrality (AGFEP, 2021).

Over the past two decades, agricultural support policies have improved grain production and farmers' incomes; however, they have also exacerbated the excessive use of chemical fertilizers and nonpoint source pollution, resulting in the increase of GHG emissions from agrifood systems. The Chinese government has therefore carried out a series of agricultural support policy reforms oriented toward green development. Since 2015, for example, China has reformed its support policies for agricultural chemicals inputs, including canceling support for the chemical fertilizer industry, promoting zero-growth action for chemical fertilizers and pesticides, returning crop residues to farmland, and promoting the reduction of agricultural chemicals and the utilization of agricultural waste. All of these have laid the foundation for promoting the green development of agriculture. China's 2060 carbon neutrality goal, however, puts forward higher requirements for the transformation of agrifood systems. Research has shown that agricultural green and low-carbon technologies comprise an important measure for achieving GHG emissions reduction in agrifood systems; specifically, these technologies can reduce GHG emissions from agrifood systems by 23 percent in 2060, compared to 2020 levels (AGFEP, 2021). Agricultural support policies are an important driving factor for promoting the application of agricultural green and low-carbon technologies, and optimizing strategies need to be further studied to promote the transformation of agrifood systems to achieve China's 2060 carbon neutrality goal.

Based on a systematic review of the reform of China's environment-related agricultural support policies, this chapter focuses on the win–win agricultural technologies for increasing production and on the concepts of green and low carbon systems to design simulations of various agricultural support policy scenarios. The China Agricultural University Agrifood Systems (CAU-AFS) model is used to analyze the impact of these different scenarios on future GHG emissions of agrifood systems and food security, and to compare their economic returns, including the environmental benefits of carbon reduction. Finally, we offer suggestions for repositioning agricultural support policies to facilitate the transformation of agrifood systems to green, low-carbon, and sustainable systems.

3.2 Support policies for sustainable agricultural development in China

Implementing agricultural support policies is a common practice in developed and developing countries (Peng, 2017; Zhang et al., 2021). At the beginning of the 21st century, China began a phase of promoting the development of agriculture through industry and the development of rural areas by urban areas (Cheng and Zhu, 2012). Since 2004, the central government has implemented successive policies that mainly involve direct subsidies for grain, general subsidies for agricultural inputs, subsidies for agricultural machinery, policies for the temporary purchase and storage of maize and soybeans, and a system of minimum purchase prices for rice and

[1] The carbon emission data in this chapter is in carbon dioxide equivalents (CO_2eq). Tons refers to metric tons throughout.

wheat. These direct agricultural subsidy policies have increased grain production and farmers' incomes (Chen et al., 2010; Liu, 2010; Huang et al., 2011; Yu et al., 2012); however, they have also indirectly resulted in the excessive use of chemical fertilizers and pesticides and have aggravated nonpoint source pollution, thus restricting the green and sustainable development of agriculture (Huang et al., 2008; Sun, 2020; Sui and Gu, 2020). Beginning in 2015, China has implemented a series of environment-oriented agricultural support policy reforms that have promoted the sustainable development of agriculture; these include reducing the use of chemical fertilizers and pesticides and recycling agricultural waste resources (Guo et al., 2021). The specific policies are as follows.

3.2.1 Reform of fertilizer industry support policies

To ensure the food supply and reduce farmers' production costs, particularly since the reform and opening up, China has implemented support policies for the fertilizer industry, including preferential taxation and electricity subsidies. China has issued successive preferential price policies for electricity in chemical fertilizer production since the 1970s. For the electricity used by chemical fertilizer enterprises with an annual production capacity of less than 300,000 tons of synthetic ammonia, the agricultural network loan repayment is exempted from CNY 0.02 per kWh.2 Since April 20, 2016, all preferential price policies for electricity in chemical fertilizer production have been canceled.3 A preferential value-added tax (VAT) policy was meanwhile started on nitrogen-potassium-phosphorous compound fertilizers in 1994. Since then, fertilizer production enterprises have enjoyed a corresponding preferential VAT policy in production, wholesale, retail, and import. From 2004 to 2011, the average annual VAT subsidy for chemical fertilizer reached CNY 30.8 billion (Li, 2014), which greatly stimulated chemical fertilizer production capacity. In 2015, China began to reform its preferential VAT policy, stipulating that from September 1, 2015, domestic and import VAT will be levied at a uniform rate of 13 percent on the sales and import of fertilizers. [4]

3.2.2 Agricultural resources and environmental subsidies

In 2014, China established agricultural resource and ecological protection subsidies for cultivated land protection, grassland ecological protection and management, fishery resource protection and utilization, comprehensive treatment of livestock and poultry manure, and other related expenditures. From 2016 to 2020, the accumulated subsidies for agricultural resources and ecological protection reached CNY 175.3 billion, with an average annual subsidy of CNY 35.1 billion.

In recent years, China has sought to achieve zero growth in the use of chemical fertilizers and pesticides. Since 2011, the state has launched a pilot subsidy for the demonstration of low-toxicity biological pesticides. In 2015, China began allocating CNY 9.96 million per year to subsidize pilot projects for low-toxicity biopesticide use in 42 major counties in 17 provinces that produced vegetables, fruits, tea, and other horticultural crops. This policy subsidizes the increased expenditure that farmers accrue from the use of low-toxicity biopesticide use; it drives the promotion of biopesticide and encourages their application.[5] The subsidies encourage farmers to use organic and slow-release fertilizers instead of chemical fertilizers; since 2017, for example, 100 counties have been selected for pilot projects around the production of fruit, vegetables, and tea, with each county receiving CNY 10 million in subsidies to promote the replacement of chemical fertilizers with organic fertilizers. Some regions subsidize the use of organic and slow-release fertilizers in grain planting; Yongjia County in Zhejiang Province, for example, subsidizes the application of slow-release fertilizers based on the purchase amount, with a subsidy of CNY 1,000 per ton and no more than 303.58 kg per acre. [6] Beijing, Jiangsu, Shanghai, Zhejiang, and other provinces have issued policies that subsidize farmers' use of commercial organic fertilizers by CNY 150 to 480 per ton; this accounts for 25 to 80 percent of the price of organic fertilizer.[7] These measures have been remarkably successful at achieving zero growth of chemical fertilizers and pesticides. In

[2]http://www.nea.gov.cn/2011-08/16/c_131052534.htm

[3] https://www.ndrc.gov.cn/xxgk/zcfb/tz/201504/t20150417_963801.html?code=&state=123

[4]http://szs.mof.gov.cn/zhengcefabu/201507/t20150730_1395713.htm

[5]http://www.moa.gov.cn/xw/zwdt/201504/t20150430_4570011.htm

[6]http://www.yj.gov.cn/art/2021/11/23/art_1229248200_3998187.html

[7]http://www.moa.gov.cn/gk/jyta/201908/t20190814_6322582.htm

2019, the total amount of pesticides used in China was 262,900 tons, marking a decrease of 37,000 tons compared with 2015. In terms of agricultural chemical fertilizers used in China, 54.036 million metric tons (Mmt) of agricultural chemical fertilizers were used in 2019, which was 6.19 Mmt less than that used in 2015. In 2020, the national organic fertilizer application area exceeded 91 million acres (37 million ha), an increase of about 50 percent from that of 2015, and the promotion area of new fertilizers such as slow-release and water-soluble fertilizers reached 40 million acres (16 million ha).[8]

The utilization of straw as fertilizer and feed is an effective way to increase soil organic matter and develop circular agriculture. Since 2008, China has allocated special funds for the improvement of soil organic matter to encourage farmers to return straw to farmland, restore green manure, and increase the application of organic fertilizers. In 2012, China subsidized the purchase of straw-decomposing inoculants for professional farmer cooperatives, big grain-production households, and farmers, setting a subsidy of CNY 91.07 per acre (CNY 224.94 per hectare) and an application rate of 12.14 kg per acre (29.98 kg per hectare).[9] In 2014, China allocated CNY 800 million in subsidies to protect cultivated land. From 2016 to 2020, China invested a total of CNY 7.7 billion to support the comprehensive utilization of straw in various provinces and to encourage enterprises and farmers to do the same.[10]

In 2014, China invested CNY 98 million to subsidize the purchase of 52,000 straw-crushing machines. This resulted in the mechanized straw-returning area reaching 97 million acres (39 million ha), an increase of 6 percent over the previous year.[11] In 2015, China again allocated CNY 90 million to subsidize the purchase of 58,900 straw-crushing machines. By 2018, China had expanded the scope of subsidies for agricultural machinery, allocating a total of CNY 1.11 billion in subsidies for the purchase of agricultural machinery and subsidizing the purchase of 39,800 straw-crushing machines and 33,100 straw-baler machines.[12]

From 2014 to 2015, China allocated CNY 360 million to carrying out pilot projects on the resource utilization of livestock and poultry manure in nine provinces (Hebei, Inner Mongolia, Jiangsu, Zhejiang, Shandong, Henan, Hunan, Fujian, and Chongqing). In 2017, China allocated CNY 2 billion to 51 large breeding counties to carry out pilot projects and supported the construction of large-scale breeding farms and centralized treatment facilities for fecal sewage by adopting the method of replacing subsidies with awards.[13] In 2019, China continued subsidizing the resource utilization of manure in large animal husbandry counties. Among them, the subsidy standard was for pilot counties with fewer than 500,000 pigs, with the cumulative upper limit of subsidy at CNY 35 million. For pilot counties with 510,000–700,000, 710,000–990,000, and more than 1 million pigs, the cumulative upper limits of subsidy were CNY 40 million, CNY 45 million, and CNY 50 million, respectively. By 2020, the central government had allocated CNY 24.87 billion in special funds to support the resource utilization of livestock and poultry manure in 585 major animal husbandry counties.[14] The equipment matching rate of fecal sewage treatment facilities in large-scale farms reached 97 percent and the comprehensive utilization rate of livestock and poultry fecal sewage reached 76 percent.

3.2.3 Ecological compensation policy

Ecological compensation is an important environmental policy for environmental protection, ecological civilization construction, and sustainable development of ecological resources (Wei and Hou, 2015). In the 21st century, with the rapid development of China's economy, ecological and environmental issues have become an important bottleneck restricting sustainable economic and social development. As an economic means to internalize external costs, ecological compensation has received attention from decision-making departments. To this end, China has adopted a series of policies and regulations to strengthen ecological protection and construction, such as returning farmland to forests, returning farmland to grassland, and grassland ecological compensation policies (Mao et al., 2002; Liu et al., 2021). In September 2021, the General Office of the Chinese Communist Party Central Committee and the General Office of the State Council issued a document entitled Opinions on Deepening

[8] http://www.ghs.moa.gov.cn/ghgl/202107/t20210716_6372084.htm
[9] http://www.moa.gov.cn/govpublic/CWS/201206/t20120606_2751150.htm
[10] https://www.ndrc.gov.cn/xwdt/gdzt/qgjnxcz/bmjncx/202006/t20200626_1232122.html?code=&state=123
[11] http://www.moa.gov.cn/govpublic/NYJXHGLS/201507/t20150708_4736291.htm
[12] http://www.moa.gov.cn/govpublic/ZZYGLS/201609/t20160905_5264266.htm
[13] http://www.zzys.moa.gov.cn/gzdt/201708/t20170811_6310254.htm
[14] http://www.moa.gov.cn/govpublic/xmsyj/202009/t20200910_6351835.htm

the Reform of the Ecological Protection Compensation System; this proposed reforming the ecological protection compensation system and speeding up the construction of the ecological civilization system. By 2025, an ecological protection compensation system that is compatible with economic and social development conditions will be largely complete; by 2035, an ecological protection compensation system that meets the requirements of ecological civilization construction in the new era will be almost entirely finalized. Studies have shown that the ecological compensation policy has played a positive role in ecological protection. Ecological compensation for returning farmland to forest can expand the channels for increasing the incomes of residents in the reserve by diversifying farmers' income sources and promoting the transfer of family labor to non-agricultural sectors. At the same time, it can break the vicious circle of ecology and poverty, enabling farmers to gradually achieve long-term income growth (Xie et al., 2021) and economic growth (Li and Shi, 2017). The grassland ecological compensation policy implemented in 2011 not only increased the income of herdsmen and improved their livelihoods but also helped protect the grassland ecosystem (Liu et al., 2021). The existing policy, however, has problems that restrict its effect; these include low compensation standards, a large gap between the balance of grass and livestock and the grazing prohibition standard, an imperfect supervision system, and a lack of corresponding guarantee mechanisms (Jin and Hu, 2014; Ye et al., 2020).

In general, the goal of China's agricultural support policies has shifted from pursuing grain output and increasing farmers' income toward environmental sustainability. In order to promote green and sustainable agricultural development, China has carried out reforms in direct agricultural subsidies, chemical reduction actions, nonpoint source pollution control, and ecological compensation. Few studies, however, have looked at repurposing China's agricultural support policies to promote the transformation of agrifood systems to contribute to China's 2060 carbon neutrality goal.

3.3 Repositioning agricultural support policies to promote GHG emissions reduction in agrifood systems

Since 2015, China has implemented reforms of environment-related agricultural support policies. The proposed 2060 carbon neutrality goal, however, has set higher requirements for the transformation of agrifood systems. Further optimizing existing agricultural support policies to reduce GHG emissions from agrifood systems requires in-depth systematic research. This section uses the CAU-AFS model to analyze the impact of agricultural support policies' optimization scenarios from the perspectives of food security, GHG emissions, and economic return on investment (ROI). The model incorporates agriculture and its processing, inputs, and intermediate input sectors such as fertilizers and pesticides. It adds the module of GHG emissions of agrifood systems, incorporating the GHG emissions of agricultural production and its intermediate inputs, thereby enabling analysis of the impact of policy changes on GHG emissions. (For a detailed introduction to the CAU-AFS model, see the appendix to Chapter 2.)

3.3.1 Simulation scenarios of agricultural support policies to promote GHG emissions reduction

This section presents eight scenarios for optimizing future agricultural support policies. The first is the baseline scenario under which we predict the future national economy and carbon emissions of agrifood systems under "business-as-usual" conditions. The forecast mainly considers factors such as future technological progress, population growth, and labor force changes. The agrifood systems model of China Agricultural University is used, with the baseline scenario as a reference and 2018 as the base year; the recursive dynamic prediction is set to 2060. (See the appendix of Chapter 2 for a detailed description of the base scenario.)

To explore ways to optimize agricultural support policies to achieve GHG emissions reduction in agrifood systems, we designed support policies based on agricultural green and low-carbon technologies and then evaluated their impacts on the economy and environment. Studies have shown that slow and controlled-release fertilizers, organic fertilizers instead of chemical fertilizers, machine deep placement of fertilizer, integrated soil-crop system management (ISSM), and system of rice intensification (SRI) can increase grain production and promote the reduction of fertilizer use and agricultural GHG emissions (Jiao et al., 2016; Xia et al., 2017; Cui et al., 2018; Zhang et al., 2020b; Liu et al., 2021; Amod et al., 2022). Alternate wetting and drying rice technology can achieve a greater GHG emission reduction effect without yield loss (IRRI, 2017; Zhang et al., 2020b). In livestock sector, adopting feed supplements technology and improving feed conversion efficiency can not only increase the output of livestock and poultry but can also reduce the GHG emissions of livestock and poultry production (Frank et al., 2019; Nayak et al., 2015; Wang et al., 2014). Adoption of technologies, however, requires additional cost investment, and business entities have shown a notable lack of enthusiasm. Given the lack of technology extension, the application of these technologies is relatively limited. Support policies therefore need to be designed for green and low-carbon technologies in planting and animal husbandry to further promote their application.

Slow and controlled-release fertilizers, organic–inorganic compound fertilizers, machine deep placement of fertilizer, and ISSM technology are the main measures for improving grain yield and fertilizer utilization efficiency. Slow and controlled-release fertilizers and organic–inorganic compound fertilizers can increase the average yield of the three major staple grains by 5 percent and can also improve the utilization efficiency of chemical fertilizers, resulting in savings in chemical fertilizer application (Zhang et al., 2020a; Xia et al., 2017). Machine deep placement of fertilizer can reduce nitrous oxide (N_2O) emissions by about 15 percent owing to improved fertilizer utilization efficiency (Guo et al., 2020). ISSM technology can increase the average yield of maize, rice, and wheat by 10.8 to 11.5 percent while reducing nitrogen application by 14.7 to 18.1 percent (Chen et al., 2014; Cui et al., 2018). We thus designed the following scenarios for optimizing agricultural support policies.

Slow and controlled-release fertilizers. The reasonable application rate for the production of the three major staple grains is 0.5 tons per hectare per year (t/ha/year), and the cost of adding a urease inhibitor is CNY 120 per ton. Investment in slow and controlled-release fertilizers therefore needs to be increased by about CNY 100 per hectare, compared with the application of chemical fertilizer alone. Assuming that 100 percent of the cost is covered by the government and the increase in yield is 1 percent, chemical fertilizer use can be reduced by 10 percent. [15]

Organic–inorganic compound fertilizer. The reasonable application amount for the three main grains is 2 t/ha/year. The price of organic–inorganic compound fertilizer is CNY 1,300 per ton (60 percent organic fertilizer), and the input cost is CNY 2,600 per hectare. A comparison of this with the cost of chemical fertilizers (about CNY 2,100 per hectare) shows that the subsidization of compound fertilizers needs to be increased by CNY 500 per hectare. Organic–inorganic compound fertilizers also require special machinery for application. The initial purchase cost of a unit is CNY 10,000, and its operating area is 6.7 ha. If the depreciation period of the machine is 10 years, then the new machinery cost per unit area is CNY 150 per hectare. The total investment should therefore increase by CNY 650 per hectare, covered by the agricultural support policies. This can increase the unit yield by 2 percent and save 40 percent on chemical fertilizers.

Machine deep placement of fertilizer. The rental cost of machinery per hectare is about CNY 400 (Guo et al., 2020). An additional investment of CNY 400 per hectare is thus required, fully borne by the government, to increase the yield per unit by 2 percent and fertilizer savings by 15 percent. Assuming that the ISSM technology only requires an additional promotion cost of CNY 450 per hectare, all borne by the government, the unit yield can increase by 5 percent and chemical fertilizers savings by 16 percent. Since the applicable crops and the effects of the above technologies are relatively similar, the possibility of applying these technologies simultaneously in the same field is very low. The percentage of area covered by the above four technologies will increase to 20 percent and 30 percent by 2030 and 2060, respectively.

SRI technology and alternate wetting and drying rice technology are technical measures to promote emissions reduction in rice production; the former can increase rice yield by 7.6 to 14.1 percent and save 20 percent on chemical fertilizer consumption (Tao and Ma, 2003; Chen et al., 2013; Wu et al., 2015). Alternate wetting and drying of rice is a labor-intensive technology and its impact on rice yield has obvious regional

[15]Considering that the conclusions of the existing literature are mainly based on the data of field experiments, the application effect at the farmer level will be reduced, as accounted for in this chapter.

differences. In some regions, the yield can be increased by 7.4 to 9.1 percent (Chen et al., 2022), whereas other regions report an 8 to 11 percent decrease in yield per unit area (Fu et al., 2015; Zhang et al., 2020b). According to the latest research from the International Rice Research Institute, the use of alternating wet and dry irrigation techniques can enable farmers to reduce methane emissions by 30 to 70 percent without yield loss (IRRI, 2017).

The scenarios are as follows. For SRI, we assumed that only CNY 450 per hectare is needed for the promotion of new unit areas, all borne by the government; the unit yield thus increases by 3 percent and the chemical fertilizer can be reduced by 20 percent. For alternate wetting and drying rice technology, the technology can reduce GHG emissions from rice fields by 50 percent without affecting rice yields. The labor cost needs to be increased by CNY 300 per hectare, which should be covered by the government. The percentage of area covered by the above two technologies will increase to 30 percent by 2030 and to 80 percent by 2060.

Feed supplements technology and feed conversion efficiency are important measures to promote GHG emission reduction in livestock. First, the addition of tea saponin and other additives can reduce GHG emissions by more than 16 percent in the production process of cattle and sheep; it also has a positive impact on the production levels of cattle, sheep, and milk products (Nayak et al., 2015; Wang et al., 2014). Frank et al. (2019) reported that adopting animal feed supplements, nitrification inhibitors, or anaerobic digesters can reduce agricultural carbon emissions by 30 to 94 percent. Making use of past studies (Frank et al., 2019; Nayak et al., 2015; Wang et al., 2014), we calculated that the cost of new feed supplements per sheep unit would be CNY 50, which would be borne by the government. Production could then increase by 1% and GHG emissions could be reduced by 30%.

Second, improving feed conversion efficiency can reduce the demand for feed in livestock, thereby reducing carbon emissions. Bai et al. (2014), for example, state that the feed conversion efficiency of pigs can be increased by 20 percent by 2030, thereby reaching the current EU level; they found that the nitrogen loss of pig feed in this scenario is reduced by 25 percent compared to the baseline scenario. New investment in livestock research and promotion can increase the output of livestock and poultry by 0.1 percent and the feed conversion efficiency rate by 20 percent, while also reducing GHG emissions by 30 percent. If the current investment in livestock research and promotion is doubled, that is, to about CNY 3.2 billion, the productivity of important livestock and poultry products will increase year by year and the carbon emission coefficient will decrease year by year. The percentage of area covered by both technologies can also increase to 50 percent and 80 percent by 2030 and 2060, respectively.

Because of the uncertainty of the conclusions of existing literature and future technological innovations, the yields and environmental effects of the above different technologies are taken as medium scenarios; on this basis, for simulation analysis they are increased by 50 percent and reduced by 25 percent to give the high and low scenarios, respectively. Table 3-1 presents an overview of these scenarios.

3.3.2 Impact of agricultural support policies

(1) Impact of technical measures for fertilizer use reduction

Investment in organic–inorganic compound fertilizers, machine deep placement of fertilizer, ISSM technology, and slow and controlled-release fertilizers can lead to an increase in grain production and self-sufficiency, resulting in a decrease in feed grain costs and an increase in the production of livestock and poultry products. Compared with the baseline scenario, under the medium scenario, in 2030, ISSM technology leads to a 0.5 to 0.6 percent increase in the production of rice, wheat, and corn, improving the self-sufficiency rate of the three major staple grains. The resulting decrease in the price of grains leads to a 0.3 percent increase in the production of livestock, poultry, and aquatic products. Organic–inorganic compound fertilizer and machine deep placement of fertilizer can increase production of grains by 0.2 to 0.3 percent and the production of livestock, poultry, and aquatic products by 0.1 to 0.2 percent. Slow and controlled-release fertilizers increase the production of the three major staple foods, livestock, poultry, and aquatic products by 0.1 percent.[16] Under the medium scenario, in 2060, owing to the increase in technology coverage, ISSM technology increases the

[16] For space reasons, only the results of the medium scenario are analyzed in the main text.

Table 3-1 Scenario Design for Low-carbon Dovelopment

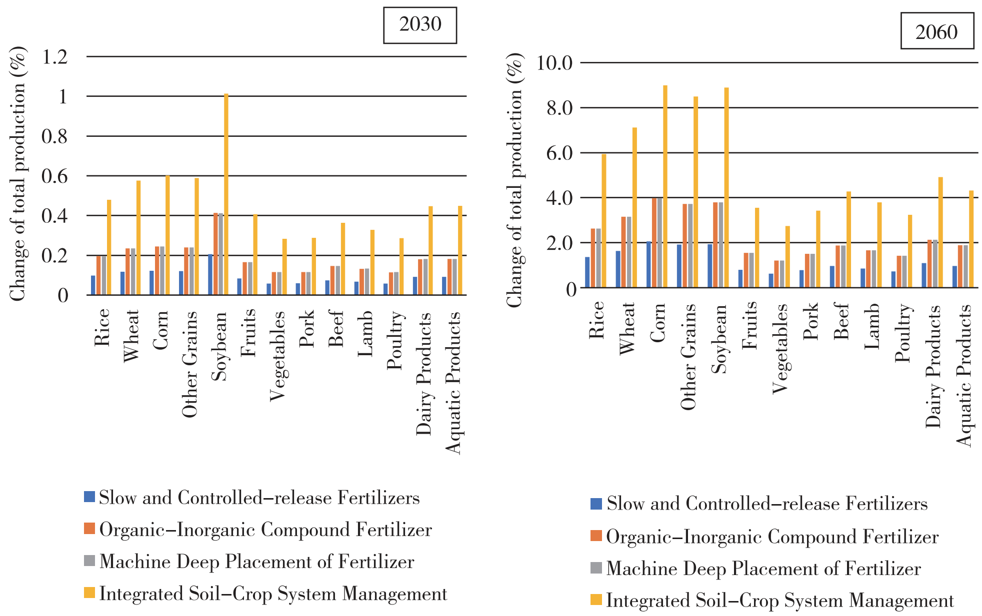
	Measures	Variety	New cost (CNY per hectare or per sheep unit)	Subsidy ratio (%)	Percentage of area covered by the technology (%)	High-level scenario	Medium-level scenario	Low-level scenario
Green and low-carbon technology in planting industry—fertilizer reduction	Slow and controlled-release fertilizers	Rice, wheat, maize	100	100	Increase to 20% and 30% by 2030 and 2060, respectively	Crop yield up 1.5%, fertilizer use down 15%	Crop yield up 1.0%, fertilizer use down 10%	Crop yield up 0.75%, fertilizer use down 7.5%
	Organic-inorganic compound fertilizers	Rice, wheat, maize	650	100		Crop yield up 3.0%, fertilizer use down 60%	Crop yield up 2.0%, fertilizer use down 40%	Crop yield up 1.75%, fertilizer use down 30%
	Machine deep placement of fertilizer	Rice, wheat, maize	400	100		Crop yield up 3.0%, fertilizer use down 22.5%	Crop yield up 2.0%, fertilizer use down 15%	Crop yield up 1.75%, fertilizer use down 11.25%
	Integrated soil-crop system management technology	Rice, wheat, maize	300	100		Crop yield up 7.5%, fertilizer use down 24%	Crop yield up 5%, fertilizer use down 16%	Crop yield up 3.75%, fertilizer use down 12%
Green and low-carbon technology in planting indusry rice emissions reduction	System of rice intensification technology	Rice	300	100	Increase to 30% and 80% by 2030 and 2060, respectively	Rice yield up 4.5%, fertilizer use down 30%	Rice yield up 3%, fertilizer use down 20%	Rice yield up 2.25%, fertilizer use down 15%
	Alternate wetting and drying rice technology	Rice	300	100		Rice field emissions down 75%	Rice field emissions down 50%	Rice field emissions down 37.5%
Green and low-carbon technology in livestock	Feed supplements technology	Cattle, sheep	50	100	Increase to 50% and 80% by 2030 and 2060, respectively	Cattle, sheep production up 1.5%, carbon emission coefficient down 45%	Cattle, sheep production up 1%, carbon emission coefficient down 30%	Cattle, sheep production up 0.75%, carbon emission coefficient down 22.5%
	Improved feed conversion efficiency technology	Pigs, cattle, sheep	CNY 3.2 billion of new investment and promotion in scientific research	–		Production of pigs, cattle, and sheep up 0.15%, GHG emission coefficient down 45%	Production of pigs, cattle, and sheep up 0.1%, GHG emissions coefficient down 30%	Production of pigs, cattle, and sheep up 0.075%, GHG emissions coefficient down 22.5%

Source: The above parameters were obtained from the existing literature.

production of staple grains, livestock, and poultry and aquatic products more significantly, that is, by 5.9 to 9.0 percent, by 3.2 percent, and by 4.3 percent, respectively. Organic–inorganic compound fertilizer and machine deep placement of fertilizer contribute 2.6 to 4.0 percent, 1.5 to 1.9 percent, and 1.9 percent to the production of staple grains, livestock and poultry, and aquatic products, respectively. Slow and controlled-release fertilizers can more dramatically increase the production of staple grains, livestock and poultry, and aquatic products by 1.4 to 2.1 percent, 1.4 to 1.9 percent, and 1.0 percent, respectively (Figure 3-1).

Investing in slow and controlled-release fertilizers, organic–inorganic compound fertilizers, machine deep

Figure 3-1 Impact of Fertilizer Reduction Technology on the Production of Major Agricultural Products – Compared with the Baseline

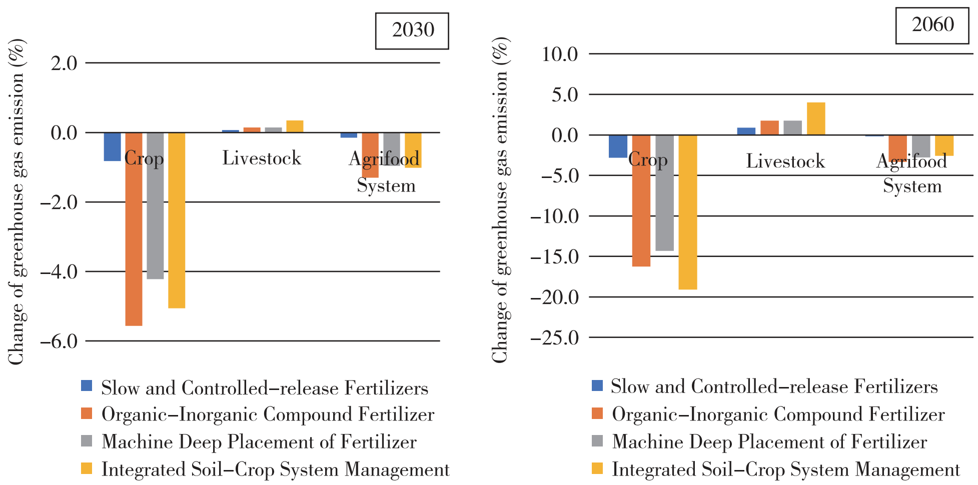


Source: Results are from the CAU-AFS model.

placement of fertilizer, and ISSM technology leads to lower GHG emissions from agrifood systems by saving on fertilizers and improving fertilizer use efficiency. Compared with the baseline scenario, the GHG emissions reduction effects of organic–inorganic compound fertilizers and ISSM technology use are more obvious by 2030 under the medium scenario, as both of them can save fertilizer application and reduce fertilizer emissions by 4.6 percent and 2.0 percent, respectively. These technologies result in a decrease in GHG emissions from crop but a slight increase in GHG emissions from livestock, which overall results in a decrease in GHG emissions from agrifood systems by 16.6 and 12.91 Mmt, respectively. Machine deep placement of fertilizer reduces fertilizer emissions by 1.8 percent by saving fertilizer usage, resulting in a decrease in GHG emissions from the agrifood systems by 12.24 Mmt. Slow and controlled-release fertilizers reduce fertilizer emissions by 1.2 percent by improving the fertilizer utilization efficiency; however, owing to the increase in GHG emissions of livestock production, the reduction in GHG emissions from agrifood systems is only 1.96 Mmt. By 2060, under the medium scenario, organic–inorganic compound fertilizer use will reduce GHG emissions from agrifood systems by 32.62 Mmt, a decline of 3.3 percent. Machine deep placement of fertilizer will reduce GHG emissions from agrifood systems by 2.8 percent or 27.32 Mmt. ISSM technology has a more significant effect, reducing GHG emissions from agrifood systems by 25.42 Mmt (2.6 percent). The GHG emissions reduction effect of slow and controlled-release fertilizers is smaller, resulting in a decrease of 1.67 Mmt (0.2 percent) from agrifood systems. Figure 3-2 graphs these trends.

The return on investment (ROI) in integrated soil-crop system management (ISSM) technology, slow and controlled-release fertilizers, and machine deep

Figure 3-2 Impact of Fertilizer Reduction Technology on GHG Emissions from Agrifood Systems – Compared with the Baseline



Source: Results are from the CAU-AFS model.

placement of fertilizer is high for agricultural GDP, agrifood systems GDP, and industrywide GDP, whereas the ROI of organic–inorganic compound fertilizers is relatively small. By 2060, the average ROI of investing in ISSM technology would be high for agricultural GDP, agrifood systems GDP, and industrywide GDP, at 6.25, 12.95, and 32.44, respectively. If the reduced carbon emissions are converted into environmental benefits at a price of CNY 60 per ton,[17] the ROI is further increased to 6.56, 13.25, and 32.75, respectively. Thus, an investment of CNY 1 can bring increases of CNY 6.56, CNY 13.25, and CNY 32.75 to agricultural GDP, agrifood systems GDP, and industrywide GDP. Slow and controlled-release fertilizers have the next-highest ROI for agricultural GDP, agrifood systems GDP, and industrywide GDP, at 5.84, 12.11, and 30.33, respectively; these figures indicate economic feasibility and the potential for further increases if the environmental benefits of carbon reduction are considered. For investment in machine deep placement of fertilizer, the ROI to agricultural GDP, agrifood systems GDP, and industrywide GDP is 2.89, 5.99, and 14.78, respectively. These values are generally feasible if the environmental benefits of carbon abatement are added. The ROI of organic–inorganic compound fertilizer to agricultural GDP, agrifood systems GDP, and industrywide GDP are lower, at 1.78, 3.68, and 8.92, respectively; they are nonetheless economically feasible and the ROI will be higher if environmental benefits are considered (Table 3-2).

Considering the uncertain impacts of fertilizer reduction technologies on grain yields and emission reduction efficiency, in the high and low scenarios of these technologies grain production varies from 1.0 to 5.4 percentage points, whereas livestock production varies by ±0.6 to 1.5 percentage points. In terms of GHG emissions, in 2060 the high and low scenarios show reductions of 2.1 to 6.5 percent in crop, increases of 0.7 to 2.4 percent in livestock, reductions of 0.7 to 1.9 percent in agricultural emissions, and reductions of 0.1 to 0.4 percent in agrifood systems (see appendix in this chapter for details). In terms of ROI, in 2060 the change in ROI under the high and low scenarios for agricultural GDP ranges from 0.9 to 3.0; for agrifood systems GDP it ranges from 1.8 to 6.2; and for industrywide GDP it ranges from 7.5 to 15.7.

(2) Impact of green low-carbon technologies on rice production

SRI technology increases rice production and the self-sufficiency rate, has positive affect on production of livestock and aquatic products, and reduces GHG emissions by saving fertilizer application. Although alternate wetting and drying rice technology has a smaller impact on rice production, it is beneficial to curbing GHG emissions in rice production. Compared

[17]The national carbon market carbon emission allowance has a closing price of CNY 58 per mt on May 9, 2022.

Table 3-2 Return on Investment (ROI) for Different Scenarios

Scenario	Without considering carbon emission reduction benefits			Considering carbon emission reduction benefits		
	Total GDP	Agrifood systems GDP	Agricultural GDP	Total GDP	Agrifood systems GDP	Agricultural GDP
Slow and controlled-release fertilizers	30.33	12.11	5.84	30.46	12.24	5.97
Organic–inorganic compound fertilizers	8.92	3.68	1.78	9.19	3.95	2.05
Machine deep placement of fertilizer	14.78	5.99	2.89	15.13	6.34	3.25
Integrated soil-crop system management technology	32.44	12.95	6.25	32.75	13.25	6.56
System of rice intensification technology	20.91	7.94	3.89	22.00	9.03	4.98
Alternate wetting and drying rice technology	-0.47	-0.01	0.00	0.87	1.33	1.35
Feed supplements technology	4.40	1.89	1.03	4.90	2.39	1.53
Improved feed conversion efficiency technology	16.74	4.23	0.67	20.17	7.66	4.10

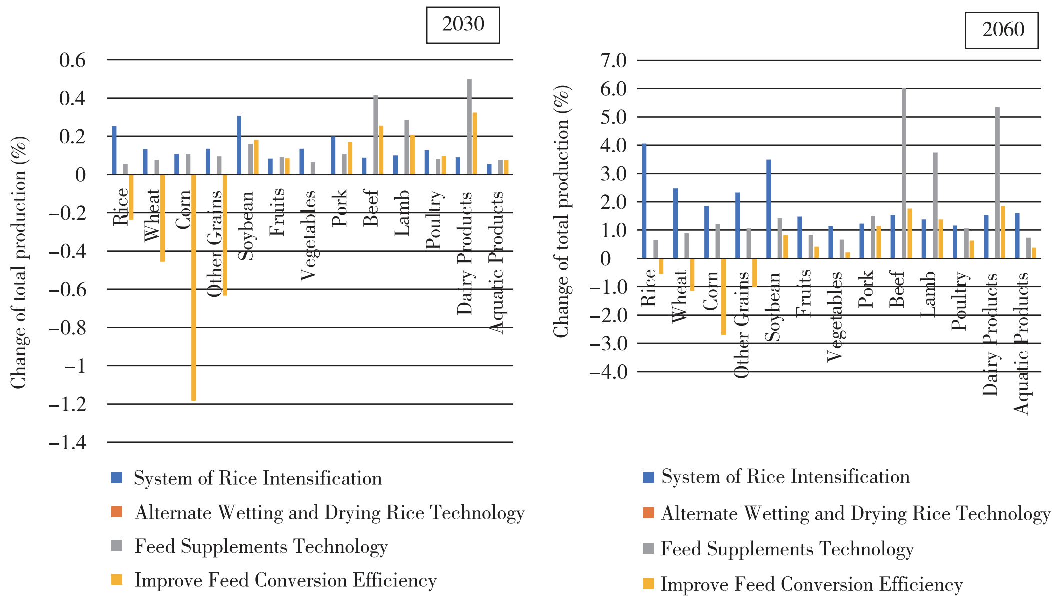
Source: Results are from the CAU-AFS model.

to the baseline scenario, under the medium scenario, in 2060 the use of SRI technology leads to a 4.1 percent increase in rice production and a 1.1 percent increase in rice self-sufficiency. The subsequent decrease in feed costs increases the production of pigs, poultry, and aquatic products by 1.1 to 1.6 percent, resulting in an increase in carbon emissions from livestock, and an overall decrease in GHG emissions from agrifood systems by 5.0 percent or 48.6 Mmt. Under the medium scenario, in 2060 the alternate wetting and drying rice technology contributes less to rice production but it decreases GHG emissions from agrifood systems by 5.2 percent or 50.5 Mmt by reducing emissions from rice production (Figures 3-3 and 3-4).

SRI technology has a high economic return for agricultural GDP, agrifood systems GDP, and industrywide GDP, while alternate wetting and drying rice technology is favorable to agricultural GDP and agrifood systems GDP when considering the environmental benefits of GHG emissions reduction. In terms of investment in carbon reduction technology in rice production, SRI technology can have an ROI of 3.9, 7.9, and 20.9 to agricultural GDP, agrifood systems GDP, and industrywide GDP in 2060, respectively, under the medium scenario. This increases to 5.0, 9.0, and 22.0, respectively, when the environmental benefits of carbon abatement are added. That is, every CNY 1 invested will increase agricultural GDP, agrifood systems GDP, and industrywide GDP by CNY 5, 9, and 22, respectively. In contrast, alternate wetting and drying rice technology has ROIs of 0, -0.01, and -0.5 to agricultural GDP, agrifood systems GDP, and industrywide GDP, respectively, indicating economic infeasibility, but if the environmental benefits of GHG emissions reduction are added, the ROIs grow to 1.35, 1.33, and 0.9 (Table 3-2).

Considering the uncertain impact of rice emissions reduction technology on rice yields and emissions reduction efficiency, in the high and low scenarios of SRI technology, rice production in 2060 varies by ±2.2 percent, whereas livestock production varies by ±0.7

Figure 3-3 Impact of Green and Low-carbon Technologies for Rice Production and Livestock on the Production of Major Agricultural Products – Compared with the Baseline



Source: Results are from the CAU-AFS model.

to 0.8 percent. In terms of GHG emissions, in 2060 the high and low scenarios have a reduction of about 7.2 percent in crop emissions, an increase of about 0.7 percent in livestock, a reduction of 1.1 percent in agricultural emissions, and a reduction of 0.6 percent in agrifood systems emissions. In terms of ROI, the change in agricultural GDP ROI is around 1.9 in the high and low scenarios, and the change in industrywide GDP ROI is around 10.2. In the high and low scenarios for the alternate wetting and drying rice technology, the reduction in GHG emissions from the crop sector is around 10.3 percent, and the reduction in carbon emissions from agrifood systems is around 2.9 percent (see appendix in this chapter for details).

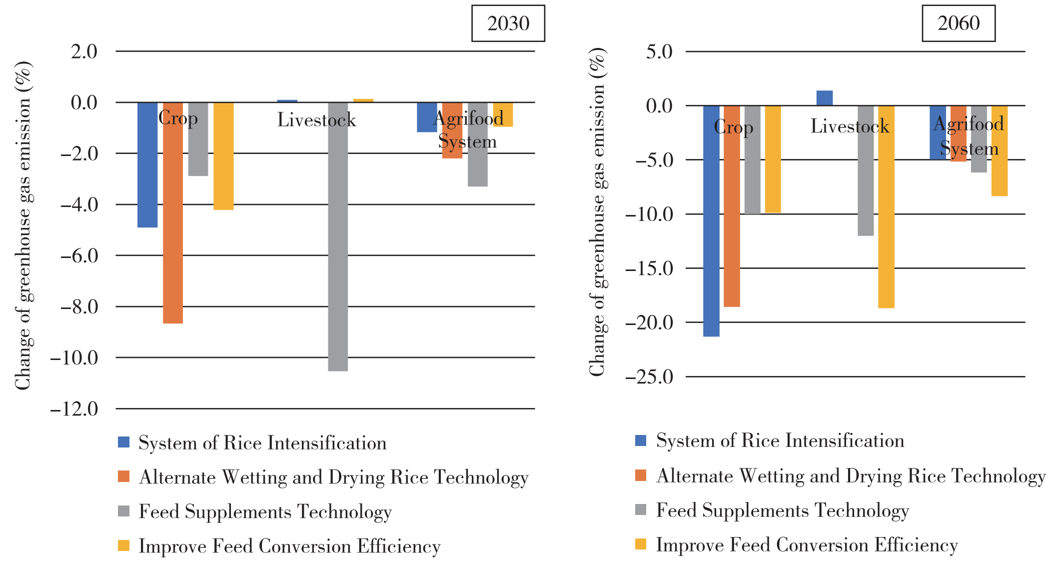
(3) Impact of green and low-carbon technologies in livestock

Investing in feed supplements technology not only brings about an increase in the production of livestock and poultry products but also contributes to the reduction of agrifood systems emissions by reducing GHG emissions in cattle and sheep production. Compared with the baseline scenario, under the medium scenario, in 2060, feed supplements technology can increase the production of cattle, sheep, milk, and other products by 3.7 to 6.0 percent. The development of the livestock and poultry industry and the demand for feed will increase significantly, pulling up the production of staple grains such as rice, wheat, and corn; this will bring about a 0.6 percent increase while causing a decrease in the area of staple grains and bringing about a reduction in emissions from crop. In addition, improvements in feed quality can lead to a decrease in GHG emissions from cattle and sheep production, ultimately resulting in a decrease in GHG emissions of 6.2 percent (60.35 Mmt) from agrifood systems by 2060.

Investment in improving feed conversion efficiency enhances livestock production and contributes to the reduction of GHG emissions from agrifood systems; it does so by reducing GHG emissions during livestock production, through feed saving. Compared with the baseline scenario, under the medium scenario, increasing feed conversion efficiency increases cattle, sheep, and milk production by 1.2 to 1.8 percent in 2060. The significant increase in feed conversion efficiency for livestock and poultry production leads to a decrease in feed demand, resulting in a 0.6 to 2.7 percent decrease in the production of rice, wheat, and corn; however, it has little impact on the self-sufficiency of the three major staple foods, which overall results in a decrease in GHG emissions of agrifood systems by 81.66 Mmt (8.3 percent) in 2060 (Figures 3-3 and 3-4).

The economic returns to agricultural GDP, agrifood systems GDP, and industrywide GDP are high for feed

Figure 3-4 Impact of Green and Low-carbon Technologies for Rice and Livestock on GHG Emissions from Agrifood Systems – Compared with the Baseline



Source: Results are from the CAU-AFS model.

supplements technology and improved feed conversion efficiency. Feed supplements technology is economically feasible with an ROI of 1.03, 1.89, and 4.40 for agricultural GDP, agrifood systems GDP, and industrywide GDP, respectively. The environmental benefits of GHG emissions reduction would further increase ROIs to 1.53, 2.39, and 4.90. Increasing feed conversion efficiency will have a positive impact on livestock development but will have a negative impact on the plantation industry. The overall ROI on agricultural GDP, agrifood systems GDP, and total industry GDP would be 0.67, 4.23, and 16.74, respectively if the environmental benefits of carbon emissions reduction are added (Table 3-2).

Considering the uncertainty related to green and low-carbon technologies for livestock production and emissions reduction efficiency, the high and low scenarios of feed supplements technology show changes of ±1.7 to 4.2 percent in 2060 for livestock production and ±0.4 to 0.8 percent for grain production. In terms of GHG emissions, reductions in livestock, agricultural, and agrifood systems emissions are, respectively, 11.4 percent, 6.0 percent, and around 3.3 percent in the high and low scenarios in 2060. In terms of ROI, agricultural GDP, agrifood systems GDP, and industrywide GDP will have changes in ROI of around 0.5, 0.9, and 2.4, respectively. In the high and low scenarios of increasing feed conversion efficiency, livestock production changes by ±0.4 to 0.7 percent, whereas grain production changes by ±0.1 to 0.2 percent. In 2060, reduction in livestock emissions in the high and low scenarios is around 16.1 percent, that in agricultural emissions is around 8.4 percent, and that in agrifood systems emissions is around 4.8 percent (see the appendix in this chapter for details). In terms of ROI, changes in the high and low scenarios in agricultural, agrifood systems, and industrywide GDP ROIs are around 0.6, 1.2, and 2.7, respectively.

Overall, reforming the existing agricultural support policies to invest in green and low-carbon technologies is aimed not only at ensuring food security but also at reducing GHG emissions from agrifood systems, which will yield positive economic returns. Compared with the baseline scenario, the medium scenario combining all the above measures can reduce GHG emissions from agrifood systems by 180 and 330 Mmt in 2030 and 2060, respectively, accounting for 14.1 percent and 33.5 percent of the total GHG emissions from agrifood systems. Among them, investment in organic–inorganic compound fertilizers, machine deep placement of fertilizer, ISSM technology, and SRI technology in plantations have better emissions reduction effects. Although the contribution of alternate wetting and drying rice technology to staple food production is smaller, it can bring a significant reduction to GHG emissions in agrifood systems, which will contribute to the positive returns of agricultural and agrifood systems GDP when considering the environmental benefits of GHG emissions reduction. The GHG emissions reduction effect of feed supplements technology and improved feed conversion efficiency in livestock are obvious. Innovation in terms of the yield and emissions reduction effects of the abovementioned technical measures will lead to greater emissions reduction in agrifood systems and will offer greater contributions to achieving China's 2060 carbon neutrality goal. Under the high scenario of the above technical measures, the GHG emissions reduction of agrifood systems will be 240 and 420 Mmt in 2030 and 2060, respectively, accounting for 18.5 percent and 42.4 percent of the total GHG emissions of agrifood systems.

3.4 Conclusion and recommendation

This chapter systematically reviewed the evolution of agricultural support policies related to resources and the environment, as well as the research progress on their environmental impacts. With the goal of increasing food production and green low-carbon production, we analyzed the emissions reduction effect of agricultural green and low-carbon technologies such as slow and controlled-release fertilizers, organic–inorganic compound fertilizers, machine deep placement of fertilizer, ISSM technology, SRI technology, alternate wetting and drying rice technology, feed supplements technology, and improved feed conversion efficiency. Using the CAU-AFS model, we designed simulation scenarios of different supporting policies for technology development and then analyzed their impacts on the environment, food production, and economic development. The main research findings are as follows.

First, since 2015, China has been promoting a green shift in agricultural support policies such as the replacement of chemical fertilizers with organic fertilizers, protection of arable land quality, and returning straw to fields. These have achieved some success. Fertilizer use in China fell 10.3 percent from 2015 to 2019, but the amount of fertilizer used per hectare is still 2.9 times the global average and 2.8 times that of the United States. Under the new context of China's 2060 carbon neutrality goal, these agricultural support policies must be optimized to promote GHG emissions reduction in agrifood systems.

Second, the repositioning of agricultural support policies to promote the application of green low-carbon technologies in agriculture can achieve a win–win situation of ensuring food security and reducing emissions. In agriculture, investments can not only guarantee food production but can also reduce GHG emissions from agrifood systems, which also has a high economic return. Although alternate wetting and drying rice technology for rice planting contributes less to rice production, it can reduce GHGs to a greater extent and it is also economically feasible if the environmental benefits are considered. For livestock also, investment in feed supplements technology and feed conversion efficiency can both promote the development of livestock and reduce GHG emissions from agrifood systems, which again has a high economic return.

Third, the comprehensive application of the abovementioned green, low-carbon technology measures can achieve a greater reduction in emissions from agrifood systems. Compared with the baseline scenario, with the goal of ensuring food security, the integrated measures can reduce GHG emissions from agrifood systems by 150 (low scenario) to 240 (high scenario) Mmt of CO_2eq, accounting for 11.8 to 18.6 percent of GHG emissions from agrifood systems in 2030; the medium scenario leads to a 14.1 percent reduction in GHG emissions from agrifood systems. By 2060, the GHG emissions from agrifood systems is reduced by 290 Mmt to 420 Mmt, accounting for 29.1 to 42.4 percent of the CO_2eq; the medium scenario leads to a 33.5 percent reduction in the GHG emissions of agrifood systems.

While supporting the goal of ensuring food security, the government should promote agricultural policy reform to facilitate the transformation of agrifood systems to make a greater contribution to China's 2060 carbon neutrality goal. Specific policy recommendations include the following. First, the government should reposition the agricultural subsidy policy system and agricultural science and technology to promote the transformation of subsidy policy and science and technology in a green, low-carbon, and sustainable direction. Second, agricultural support policies should be reformed to promote the R&D, application, and promotion of high-efficiency, green, low-carbon, and other multi-win technologies, machinery, and equipment, as well as green and smart fertilizers. The policies should also pay attention to the role of social service organizations in the application of green and low-carbon technologies in agriculture and should promote the active participation of farmers in green agricultural development. Third, the government should establish a carbon market mechanism for agrifood systems and should improve the distribution mechanism for carbon emission reduction proceeds to attract fertilizer enterprises, food processing enterprises, social service organizations, farmers, and other stakeholders to participate and to share the benefits from carbon emissions reduction.

This chapter does not discuss new breakthrough agricultural technologies such as smart fertilizers, biological nitrogen-fixing technology, breeding technology, or other technologies that have great potential for food security and GHG emissions reduction, because the application costs, contribution to per unit yield, and GHG emissions reduction potential of these technologies are not yet clear. As related research continues, the GHG emissions reduction effects of these new technologies will become clearer and they will certainly become a more powerful measure to promote GHG emissions reduction in agrifood systems. These uncertainties need to be studied thoroughly in the future, but do not affect the main conclusions and recommendations of this chapter.

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Appendix

Table 1 Impacts of Different Simulation Scenarios on GHG Emissions from Agrifood Systems Compared with the Baseline

Unit: 10,000 metric tons of CO_2eq

Year	Scenario	Area covered by the technology (%)	Crop			Livestock			Agrifood systems		
			High	Medium	Low	High	Medium	Low	High	Medium	Low
2030	Slow and controlled-release fertilizers	20	-399	-266	-200	33	22	17	-294	-196	-147
	Organic–inorganic compound fertilizer	20	-2229	-1799	-1799	66	44	33	-2021	-1660	-1478
	Machine deep placement of fertilizer	20	-1587	-1363	-1255	66	44	33	-1379	-1224	-1150
	Integrated soil-crop system management technology	20	-1981	-1634	-1459	162	109	82	-1473	-1291	-1200
	System of rice intensification technology	30	-1899	-1583	-1423	42	29	22	-1757	-1487	-1350
	Alternate wetting and drying rice technology	30	-3733	-2798	-2331	0	0	0	-3733	-2798	-2331
	Feed supplements technology	50	-937	-934	-933	-4996	-3324	-2490	-5860	-4209	-3387
	Improve feed conversion efficiency technology	50	-919	-919	-919	-6284	-4170	-3113	-7198	-5090	-4036
2060	Slow and controlled-release fertilizers	30	-1146	-768	-577	396	268	203	-259	-168	-124
	Organic–inorganic compound fertilizer	30	-5242	-4425	-4004	758	520	396	-3548	-3262	-3119
	Machine deep placement of fertilizer	30	-4490	-3897	-3897	758	520	396	-2795	-2732	-2714
	Integrated soil-crop system management technology	30	-6372	-5200	-4590	1651	1189	926	-2682	-2543	-2519
	System of rice intensification technology	80	-7014	-5798	-5063	553	416	332	-5768	-4861	-4316
	Alternate wetting and drying rice technology	80	-6910	-5051	-4121	0	0	0	-6910	-5051	-4121
	Feed supplements technology	80	-2732	-2720	-2714	-5860	-3573	-2485	-8217	-6035	-5002
	Improve feed conversion efficiency technology	80	-2694	-2691	-2690	-8741	-5547	-3960	-11326	-8165	-6593

Note: Results are from the CAU-AFS model.

Chapter 4

Repurposing Agricultural Support Policies for Improved Nutritional Outcomes and Green and Low-Carbon Development

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Key Findings

● Although the full removal of cereal subsidies has some positive effects in terms of improving diets and reducing carbon emissions, it has negative impacts on food security and rural household incomes. It would lead to an approximately 20 percent increase in the price of cereals, a 2 percent drop in cereal production, and a 50 percent increase in import. The increased cereal prices would also have an adverse effect on the production of other agricultural products such as livestock products. If, however, half of the cereal subsidy is used to subsidize the production of foods with high nutritional value and low-carbon emissions, then food security and farmers' agricultural incomes would be only modestly affected, dietary quality would be improved, and agrifood system emissions would be reduced by about 0.3 percent compared with the 2030 baseline.

● High-standard farmland construction can enhance the comprehensive production capacity for grain. The return on investment is also high, and long-term return on investment of the national GDP can reach 10 yuan for every 1 yuan invested. By improving the efficiency of fertilizer use, the establishment of 20 million hectare of high-standard farmland could reduce carbon emissions from crops by about 5 percent.

● If investment in agricultural R&D and extension for green technologies is doubled, then agricultural carbon emissions could be reduced by nearly 30 percent, and intake of nutritional and healthy foods can increase for 10 percent of rural residents and 33 percent of urban residents. The long-term return on investment for the national GDP could be as high as 32 yuan for every yuan invested.

Policy Recommendations

- To achieve the multiple goals of national development, an evaluation is needed of the comprehensive impacts (and trade-offs) of agricultural support policies on food security, economic efficiency, human nutrition and health, and the environment. Agricultural support policies should be reformed accordingly with the aim of promoting agrifood system transformation.
- Agricultural support policies should be further optimized with the aim of ensuring food security, appropriately adjusting the structure of subsidies for different agricultural products and supporting the production of food with high nutritional value and low carbon emissions. The overarching goals should be to better meet citizens' needs for nutritious and healthy food and to reduce environmental impact.
- Public agricultural investment should be further increased. Increases in public investment are needed, for example, in high-standard farmland construction and in green agricultural R&D and extension, which can achieve China's multiple goals of improved nutritional outcomes, green development, and lower carbon emissions.

4.1 Introduction

China's economy has developed rapidly in recent years, achieved historic reductions in poverty, and has met the ambitious goal of creating a moderately prosperous society. In this new stage, the Chinese government has announced multiple development goals, including improving national nutrition and health, achieving green, low-carbon, and sustainable development, and achieving common prosperity, and made commitments to reach its carbon emission peak before 2030 and achieve carbon neutrality before 2060. Great changes have taken place in China's agrifood systems in this process, with a significant increase in agricultural productivity, extension of supply chains, an increased supply of agricultural products, and a significant improvement in residents' food consumption, nutrition, and health. Agricultural support policies have played an important role in promoting agrifood systems transformation, increasing agricultural production, ensuring food quantity, and providing residents with abundant and diverse food.

However, China's agrifood system still faces challenges such as the double burden of malnutrition (overweight/obesity and undernutrition) and tight resource constraints. To solve the problems in the agrifood system and achieve the multiple development goals, agricultural support policies must be optimized to promote agrifood system transformation.

On the basis of the analysis of the impacts of various policies on household diets and nutrition in Chapter 2 and on carbon emissions in Chapter 3, the current chapter aims to systematically evaluate the comprehensive impacts of different agricultural support policies on the agrifood system, including human nutrition and health, greening and low carbon emissions. We use the China Agricultural University AgriFood System Model of (CAU-AFS) and provide the scientific evidence for policy decision-makers to balance the multiple goals. This chapter focuses on adjustment of the agricultural producer subsidy structure and of public investment in agriculture. Five policies scenarios are analyzed, and they include removing all producer subsidies for cereals, transferring half or all of the subsidies to support nutritional and low-carbon food products, increasing public investment for development of high-standard farmland, and increasing expenditure on R&D and on extension for green agriculture. Based on the simulation results, this chapter puts forward policy recommendations for improving agricultural support policies.

4.2 Literature review on the impacts of agricultural support policies on nutritional and healthy diets and on green and low-carbon development

Several international organizations have explored possible reforms of global agricultural support policies, using a computable general equilibrium (CGE) model and a partial equilibrium model to simulate the possible comprehensive impacts of various policy reforms (Gautam et al., 2022). These studies found that simply removing producer support policies would result in a decline in agricultural output, an increase in the cost of a healthy diet, a significant decrease in farmers' incomes and their nutrition and health, an increase in the output of high-emission intensity products such as ruminants, with limited changes in environment improvement such as greenhouse gas emissions, thus failing to achieve sustainable agricultural development (FAO et al., 2021; Gautam et al., 2022; GPAFSN, 2020). Therefore, rather than simply removing agricultural subsidies, reforms and restructuring of the agricultural subsidies should be pursued (Laborde et al., 2021). There are three main pathways for reforming agricultural support policies. The first pathway is to shift subsidies for cereals to foods with high nutritional value and low carbon emissions, which will both increase the production of healthy foods such as vegetables and fruits and improve global health, and also reduce global greenhouse gas (GHG) emissions (GPAFSN, 2020; IFAD, 2021; Springmann and Freund, 2022). The second one is to build the linkages between agricultural support policies and positive environmental outcomes, such as increasing subsidies for environmentally friendly technologies that can significantly reduce carbon emissions while have little impact on agricultural production (M'Barek et al., 2017). The pathway is to transfer the agricultural support for producers to general public services. Increasing support for general services, especially agricultural R&D and infrastructure construction, can increase global agricultural output, increase farmers' income, reduce negative impacts on the environment, and achieve multiple sustainable development goals, including increasing agricultural output, increasing farmers' income, improving human nutrition and health, and enhancing sustainable agricultural development (Springmann and Freund, 2022; FAO et al., 2021; Gautam et al., 2022; IFAD, 2021; GPAFSN, 2020; FOLU, 2019).

Since 2004, the Chinese government has attached great importance to agricultural development and has formulated a variety of agricultural support policies and achieved remarkable results. In relation to nutrition and health, various price support policies that distort the market have been gradually eliminated since 2015, the agricultural production structure has been continuously adjusted, and the vegetable and fruit sectors have developed rapidly. The increasingly supply of agricultural products has met residents' diversified consumption demand, and their dietary quality has been significantly improved. In terms of natural resources and environment, the Chinese government has increased green support policies to promote the green and high-quality development of agriculture. First, the government has been accelerating the reform of agricultural support policies to comprehensively promote the green development of agriculture. In 2016, the Ministry of Finance and the Ministry of Agricultural and Rural Affairs (MARA) jointly issued the *Reform Program for Establishing a Green Ecology-Oriented Agricultural Subsidy System*, which aims to improve the accuracy, targeting, and effectiveness of agricultural subsidy policies, promote sustainable development of agriculture and accelerate the process of agricultural modernization. According to the statistics from the Ministry of Finance, the fiscal expenditure on the protection and use of agricultural resources has increased significantly, from 16.3 billion CNY in 2011 to 45.8 billion CNY in 2020. This expenditure is used to protect arable land and improve its quality, protect and govern grassland ecosystems, protect and utilize fishery resources, and comprehensively manage livestock and poultry manure so as to guarantee the sustainable development of agriculture. Second, the Chinese government has prioritized promoting green and high-quality agricultural development through the innovation of agricultural science and technology (S&T). In 2017, the General Office of the CPC Central Committee and the General Office of the State Council released the *Opinions on Innovative System and Mechanism to Promote the Green Development of Agriculture*. In 2018, MARA formulated the *Technical Guidelines for Green Development of Agriculture (2018–2030)*. Innovation and optimal management for low-carbon technologies are a major focus (Li and Xu, 2022). Finally, the government has put great emphasis on public agricultural investment to lay solid foundation for agricultural production and improve agricultural productivity. In 2020, about 53 million ha (800 million mu) of high-standard farmland was developed nationwide. In 2021, the National Development and Reform Commission released the *National High-Standard Farmland Construction Plan (2021-2030)* (MARA, 2021), proposing that 80 million ha (1.2 billion mu) of high-standard farmland be constructed to guarantee grain production of more than 600 million tons by 2030. The high-standard farmland can improve the efficiency of water and soil use. In addition, on high-standard farmland, the effectiveness of irrigation utilization can be increased by more than 10 percent, and the pesticide-saving and fertilizer-saving rates by more than 10 percent. One study shows that the construction of high-standard farmland can reduce carbon emissions by 24 percent (Chen and Wang, 2022).

4.3 Scenario design

In order to optimize agricultural support policies and promote transformation of China's agrifood systems, this study simulated the effects of different reforms to agricultural support schemes and agricultural public investment on food security, economic benefits, nutrition and health, and carbon emissions using the CAU-AFS Model. This model is an extension of the China General Equilibrium Model (CGE Model) with two modules: microsimulation of residents' dietary quality and of the carbon emissions of the agrifood system. Therefore, the CAU-AFS can be used for evaluation and analysis of the multiple goals of agricultural policy and investment. More details on CAU-AFS are presented in the Appendix of Chapter 2. The baseline and other five scenarios are presented in Table 4-1.

Table 4-1 Scenario Design

Scenario	Scenario name	Specific contents
Baseline (BASE)	Baseline	A business-as-usual scenario without policy changes, projects future national economic development, food production and consumption, and carbon emissions to 2060 based on projections of demographics and labor force, technological progress, etc.
Scenario1 (SUB0)	Removal of cereal producer subsidies	Removal all producer subsidies for cereals, which is equivalent to 20% of rice output value, 19% for wheat, and 17% for corn, assuming removal in all years after 2022
Scenario2 (SUB50)	Shift half of cereal producer subsidies to subsidize nutritious and low-carbon food	Shifting half of the producer subsidies for rice, wheat, and corn to support fruit, poultry, and aquatic products, which is equivalent to subsidizing 4.85% of the output value of these products, based on the same fiscal expenditure, assuming adjustments in all years after 2022
Scenario3 (SUB100)	Shift entire cereal producer subsidy to subsidize nutritious and low-carbon food	Shifting all of the producer subsidies for rice, wheat, and corn to support fruit, poultry, and aquatic products, which is equivalent to subsidizing 9.75% of the output value of these products, based on the same fiscal expenditure, assuming adjustments in all years after 2022
Scenario4 (INV-AND)	Increase investment in high-standard farmland	Increasing the development of high-standard farmland by 20 million ha (300 million mu), with a subsidy rate of 45,000 CNY/ha (3,000 CNY/mu), for a total investment of about 900 billion CNY and 15% of self-financing. The objectives are a 15% increase in yield and 10% increase in fertilizer utilization efficiency, assuming gradual completion by 2030. In order to analyze the impact of uncertainty, high and low scenarios are designed, assuming a 20% increase in yield for the high scenario and a 10% increase for the low scenario; and in terms of fertilizer savings, the high scenario improves fertilizer utilization efficiency by 12.5% and the low scenario by 7.5%
Scenario5 (INV-RD)	Increase investment in green agricultural R&D and extension	Increasing the investment in R&D and extension for efficient, low-carbon green technologies, assuming double the current investment in agricultural research (an increase of about 70 billion CNY per year, with the goal of achieving a 1% per year increase in productivity of important agricultural products, and a 25% decrease in various carbon emission factors and a 25% increase in feed conversion rates by 2060. In order to consider the impact of uncertainties, high and low scenarios are designed, with the high scenario achieving a 1.25% increase in yield per year, 30% increase in feed conversion rate and 30% decrease in carbon emission factor by 2060; low scenario achieving a 0.75% increase in yield per year, 20% increase in feed conversion rate, and 20% decrease in carbon emission factor by 2060.

The baseline is the "business-as-usual" scenario, which is used as a reference scenario. It is used to project the future changes in national economic development, agricultural production, and food consumption, as well as the carbon emissions of the agrifood system under the existing policies, accounting for future changes in factors such as technology, population, and labor. The CAU-AFS Model takes 2018 as the base year, which is recursively simulated to 2060.

Other scenarios assume that the existing agricultural support policies are adjusted. At present, China's agricultural producer subsidies focus on supporting cereals production. However, Chinese cereal consumption is declining, while the demand for other food such as fruits, vegetables, and aquatic products is increasing. Therefore, we focus on evaluating the integrated impact of policies, including on food security, farmers' income, human health, and the environment.

Scenario 1 (SUB0) assumes that the producer subsidies for rice, wheat, and corn are removed. Scenario 2 (SUB50) assumes that half of the subsidies for cereals production are transferred to food with high nutritional value and low carbon emissions, such as fruits, poultry, and aquatic products. Scenario 3 (SUB100) assumes that all subsidies for cereals production are shifted to the nutritious and low-carbon food.

In addition to optimizing subsidy policies, public investment should be increased to support the production of nutritious and low-carbon food and build an environmentally friendly food system conducive to people's nutrition and health. Therefore, two scenarios for public investment in agriculture are considered: 1) the construction of high-standard farmland of water-saving and fertilizer-saving; 2) the investment in green agricultural R&D and extension. Scenario 4 (INV-LAND) analyzes the impact of investment in high-standard farmland. The National High-Standard Farmland Construction Plan (2021–2030) calls for development of 80 million ha (1.2 billion mu) of high-standard farmland by 2030. Therefore, Scenario 4 assumes that 1) about 20 million hectares (300 million mu) of high-standard farmland will be developed between 2022 and 2030; 2) the government will invest 45,000 CNY/ha (3,000 CNHY/mu); 3) the country's comprehensive agricultural development projects are mainly directed to development of high-standard farmland, of which the proportion of self-raised funds is about 15 percent; and 4) the goal is to increase grain production by 10 to 20 percent and fertilizer utilization efficiency by 10 percent.

Scenario 5 (INV-RD) increases investment in green agricultural R&D and extension. The goal is to both increase productivity for important agricultural products and reduce carbon emissions, with all carbon emission coefficients declining by 20 to 30 percent by 2060. Since it is difficult to estimate the actual funding requirements for green agricultural R&D and extension to achieve these goals, we assume that 1) current investment in agricultural R&D and extension will be doubled, that is, to about 70 billion CNY per year, and 2) investment in green R&D and extension will increase the productivity of important agricultural products and reduce the carbon emission factors year by year. Considering the uncertainties of the impact of public investment on productivity and carbon emissions, three scenarios (high, medium, and low impact) are designed for Scenarios 4 and 5, as shown in Table 4-1.

4.4 Simulation results of the adjustment of agricultural subsidy

The removal or adjustment of producer subsidies for cereals, the increase of investment in high-standard farmland and green agricultural R&D and extension have long-term effects. In the interest of space, here we only discuss the simulation results for 2030 and 2060.

(1) Simulation results of removal of producer subsidies for cereals

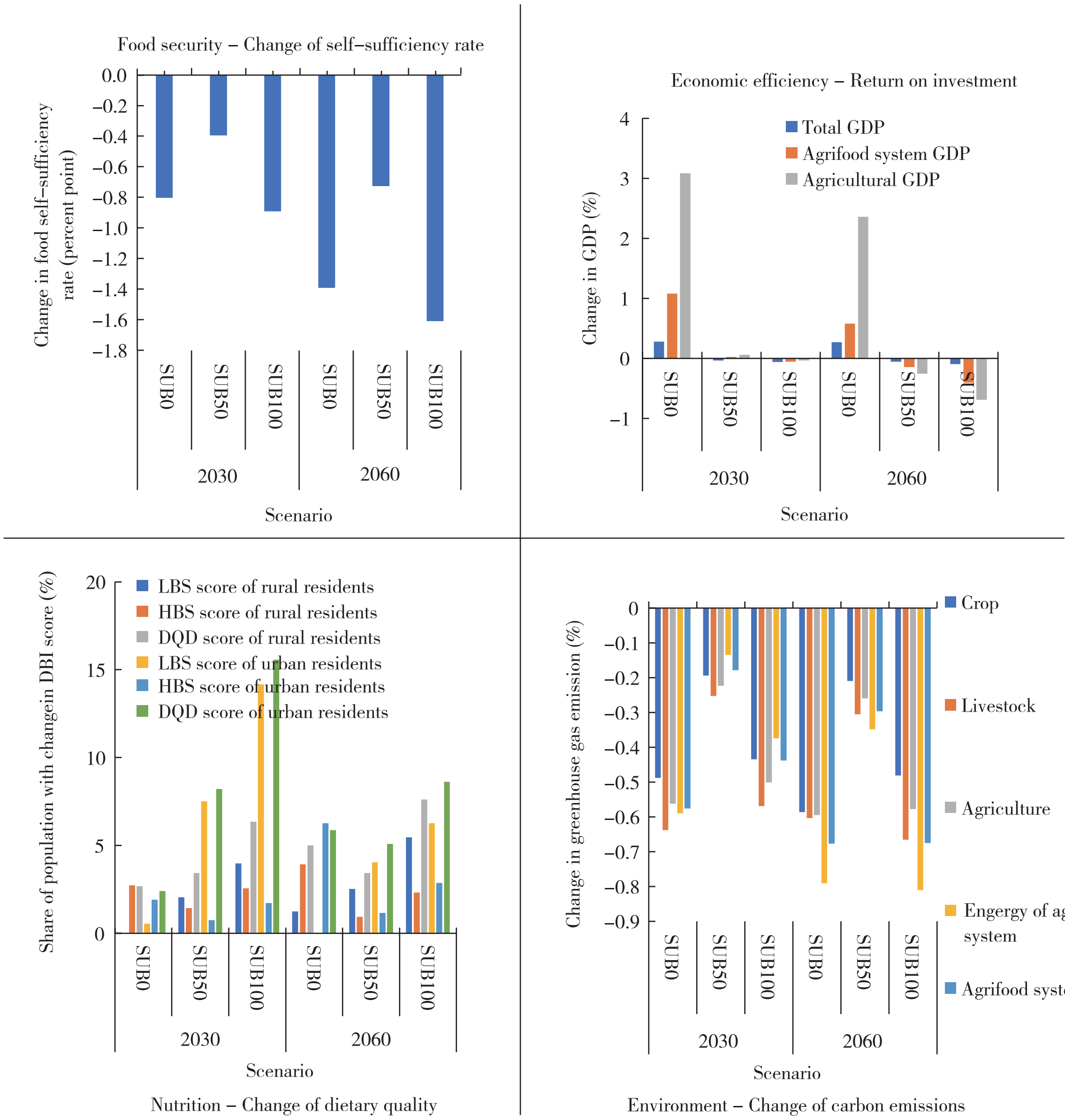
If the producer subsidies for cereals are removed, production costs increase, the prices rises, output decrease, and imports increase, as shown in Table 4-2. Compared with the baseline, in 2030, the output of the main cereals decrease by about 2 percent, with a decrease of 4.7 million tons for rice, 3.36 million tons for wheat, and 6.01 million tons for corn. The prices rise by 22 percent, 21 percent, and 18 percent, respectively, and imports increase by 46 percent, 44 percent, and 38 percent, respectively. In addition, the removal of cereal subsidies leads to an increase in feed grain prices and production costs for livestock products, and to a decrease in the output of pork, poultry, dairy products, and aquatic products, which decline by 0.5 percent, 0.5 percent, 1.2 percent, and 0.8 percent, respectively. Rising agricultural product prices also increase intermediate input costs for agro-processing industries, which leads to a decrease in the output of processed products. The output of milled cereal products and the animal feed processing industry decreases by 1.6 percent, and the output of slaughtering, meat processing, and aquatic products processing decreases by about 1.2 percent. In 2060, the output, price, and import of the agricultural products change in the same direction as in 2030, with a slightly larger effect.

The removal of subsidies affects the income of rural residents, especially low-income rural residents. Compared with the baseline, in 2030, the income of rural residents declines by an average of 0.1 percent, and the income of low-income rural residents declines by 0.2 percent. In 2060, the income of rural residents and low-income rural residents declines by 0.3 percent and 0.5

percent, respectively.

Affected by the rise in cereals prices, urban and rural residents' consumption of cereals and meat decrease and the consumption structure changes. Rural residents' consumption is more affected than urban residents', and low-income rural residents are most affected. Compared with the baseline, in 2030, the consumption of cereals for urban and rural residents decreases by an average of 0.2 to 0.3 percent. In 2060, consumption of cereals by urban and rural residents declines by about 0.3 percent, and the consumption of fruits and vegetables increases by 0.3 percent and 0.2 percent, respectively (Table 4-2). The dietary quality of residents is slightly improved, and the high bound score (HBS) of excessive intake decreases in 4.4 percent of low-income rural residents and 2.8 percent of low-income urban residents, as shown in Figure 4-1.

Figure 4-1 Impacts of Adjustments of Producer Subsidy on Food Security, Nutrition and Environment – Compared with the Baseline



Source: Results are from the CAU-AFS model.

Since cereals and livestock products are important sources of agricultural carbon emissions, the decline in of production of cereals and livestock products reduces carbon emissions, as shown in Figure 4-1. Compared with the baseline, GHG emissions from crops and livestock decline by 0.5 percent and 0. 6 percent, respectively, and the emissions from agrifood systems declines by 7.33 million tons (0.6 percent). In 2060, the emissions from crops and animal livestock decreases by about 0.6 percent, and the GHG emissions of agrifood systems by 0.7 percent.

Overall, removal of subsidies for cereals has a negative impact on food quantity and farmers' incomes, but it also contributes to improving the quality of residents' diets and reducing emissions.

(2) Simulation results of shifting producer subsidies for cereals to nutritious and low-carbon foods

In Scenario 2, half of the producer subsidies for cereals are shifted to subsidize nutritious and low-carbon food. The simulation results are shown in Table 4-2. Compared with the baseline, in 2030, the price of rice, wheat, and corn increases by 9 to 10 percent, the yield decreases by about 0.8 percent, and imports increase by about 20 percent. As a result of increased subsidies for fruits, aquatic products, and poultry meat, production of these products increases by 1.9 percent, 1.6 percent, and 0.2 percent, respectively. The small increase in poultry production is explained by the increase in feed grain prices, which offsets the incentive effects of subsidies. Prices of both fruits and aquatic products decrease by about 4.5 percent. The trends in 2060 are similar to those in 2030.

When all the producer subsidies for cereals are shifted to subsidize nutritious and low-carbon foods (Scenario 3), the direction of change in the production of agricultural products will remain the same, but the magnitude will be greater, as shown in Table 4-2. Compared with the baseline, in 2030, cereals prices increase by 19 to 23 percent, production decreases by 1.5 to 2 percent, and the import volume increases by 40 to 50 percent. At the same time, the production and price changes of fruits, aquatic products, and poultry meat are more significant, with production increasing by 3.7 percent, 3.0 percent, and 0.3 percent, respectively, and prices falling by 9.1 percent, 7.7 percent, and 5.7 percent, respectively. The results in 2060 are similar to those in 2030.

Due to the changes in food prices, consumption of cereals decreases, consumption of fruits, poultry meat, and aquatic products increases significantly, the structure of residents' food consumption is more balanced, and the quality of diets improves, as shown in Figure 4-1. In 2030, consumption of cereals decreases slightly, while consumption of fruits increases by about 3 percent, and the consumption of poultry meat and aquatic products will increase by 0.5 percent and 1.1 percent, respectively, with rural residents' consumption increasing slightly more than urban residents' under this scenario compared with the baseline. Dietary quality improves, as diet quality distance (DQD) increases for 3.4 percent of rural residents, and the intake deficiency score (low bound score, LBS) decreases for 7.5 percent of urban residents. The results in 2060 are similar to those in 2030.

Under Scenario 3 (shifting all cereals subsidies to fruits, poultry, and aquatic products), the improvement in the quality of residents' diet is more significant, as shown in Figure 4-1. In 2030, dietary quality (diet quality distance, DQD) improves for 6.3 percent of rural residents, for 7.5 percent of urban residents, the low bound score (LBS) improves. In 2060, the change in the quality of residents' diets is even more pronounced.

GHG emissions from agrifood systems decline due to structural adjustments in food production, as shown in Figure 4-1. Compared with the baseline, under Scenario 2, GHG emissions from agrifood systems fall by about 0.3 to 0.4 percent by 2060, equivalent to 2.9 to 6.61 million tons of carbon dioxide. And under the scenario of SUB100, GHG emissions from agrifood systems will reduce by about 0.4-0.7%.

In general, the complete removal or shift of all producer subsidies for cereals will lead to a sharp rise in food prices and a sharp decline in production, an increase in imports, and a decline in farmers' incomes, which will also have an impact on the production of other products such as livestock products. However, if the subsidies for cereals producers are reduced appropriately and the funds are transferred to subsidize the production of nutritious and low-carbon foods, the dietary quality of residents will improve and the carbon emissions will decrease.

Table 4-2 Impact of Adjustments of Producer Subsidies on Food Supply and Demand in 2030 and 2060–Compared to the Baseline

Commodity	2030												2060											
	Removal of cereals subsidies(SUB0)				Shift half of cereals subsidies(SUB50)				Shift all cereals subsidies(-SUB100)				Removal of cereals subsidies(SUB0)				Shift half of cereals subsidies(SUB50)				Shift all cereals subsidies(-SUB100)			
	P	Q	M	C	P	Q	M	C	P	Q	M	C	P	Q	M	C	P	Q	M	C	P	Q	M	C
Rice	21.9	-2.1	46.2	-0.3	10.3	-0.8	20.8	-0.1	22.8	-1.8	48.6	-0.3	21.3	-2.8	44.2	-0.3	10.3	-1.2	20.4	-0.2	22.7	-2.6	47.2	-0.3
Wheat	21.2	-2.3	44.4	-0.3	10.1	-0.9	20.2	-0.1	22.2	-1.9	46.9	-0.3	20.7	-3.3	42.1	-0.3	10	-1.3	19.7	-0.2	22.1	-2.9	45.3	-0.3
Maize	18.3	-2	38	-0.2	8.9	-0.7	17.9	-0.1	19.4	-1.5	40.8	-0.2	17.8	-3.6	34.8	-0.2	8.9	-1.5	16.8	-0.1	19.2	-3.4	37.8	-0.3
Other cereals	-0.4	-1.5	-1.9	0	0.2	-0.6	-0.1	0	0.3	-1.4	-0.5	0	-0.9	-2.6	-3.5	0	0.2	-1.3	-0.8	0	0.2	-2.8	-2	0
Soybean	-0.6	0.2	-0.4	-0.1	0.2	-0.3	0.1	0	0.2	-0.6	0.1	-0.1	-1	0.6	-0.5	-0.1	0.1	-0.3	0.1	0	0.1	-0.5	0.1	0
Fruits	-0.8	-0.1	-1.1	0.1	-4.7	1.9	-7.5	3.3	-9.1	3.7	-14.3	6.6	-1.1	0.1	-1.3	0.3	-4.7	2.1	-7.2	3.2	-9.1	4.2	-13.7	6.5
Vegetables	-0.8	-0.3	-1.3	0	0.2	0	0.5	-0.1	0.4	-0.1	0.9	-0.2	-1.1	-0.3	-1.7	0.2	0.2	0	0.5	-0.1	0.2	0	0.8	-0.2
Pork	1.8	-0.5	3.7	-0.2	1.3	-0.2	2.5	-0.1	2.8	-0.4	5.4	-0.2	0.8	-0.5	2	-0.1	1	-0.2	1.9	-0.1	2	-0.4	4	-0.2
Beef	1.3	-0.6	2.7	-0.2	1.1	-0.3	2	-0.1	2.3	-0.6	4.3	-0.3	0.4	-0.5	1.2	-0.1	0.8	-0.3	1.5	-0.1	1.7	-0.7	3	-0.3
Mutton	0.9	-0.5	1.8	-0.2	1	-0.2	1.8	-0.1	2	-0.4	3.7	-0.3	0.1	-0.4	0.6	-0.1	0.7	-0.2	1.3	-0.1	1.4	-0.5	2.6	-0.2
Poultry	3.2	-0.5	6.6	-0.6	-3.1	0.2	-5.9	0.5	-5.7	0.3	-10.7	0.9	2.8	-0.4	6.1	-0.7	-3.1	0.2	-5.8	0.6	-5.8	0.4	-10.6	1.2
Dairy	3	-1.2	5.4	-1.4	1.7	-0.6	3	-0.7	3.7	-1.3	6.5	-1.5	2.9	-1.5	5.3	-1.7	1.8	-0.8	3	-0.9	3.9	-1.7	6.5	-2
Aquatic product	0.8	-0.8	1.3	-0.4	-4	1.6	-6.5	1.1	-7.7	3	-12.1	2.2	0.5	-0.8	1	-0.4	-4	1.7	-6.2	1.5	-7.7	3.3	-11.7	2.9

Source: Results are from the CAU-AFS model.

Note: P=Price, Q=Production, M=Import, C=Consumption.

4.5 Effect assessment of public investment in agriculture

(1) Simulation results of the increase of public investment in the development of high-standard farmland

Increasing public investment in the construction of high-standard farmland increases the output and decreases the price of grain and other crops, which also reduces the feed cost and increases the output of livestock products (see Table 4-3 for more details). Compared with the baseline, in 2030, the output of grains increases by more than 1 percent, imports decrease by 19 to 21 percent, and grain prices decrease by 10 to 12 percent. The decline in grain prices is conducive to the development of animal husbandry. The output of pork, beef, mutton, poultry, milk, and other livestock products as well as aquatic products increases by 1 percent, prices decrease by 2 to 3 percent, and imports decrease by 3 to 5 percent. In 2060, the trend is agricultural production is the same. Due to the expansion high-standard farmland, the change in output is greater than in 2030. In 2060, cereals production increases by more than 3 percent, imports decrease by 23 percent, and prices decline by 13 to 14 percent. The output of pork, beef, mutton, poultry, milk, and other livestock products and aquatic products increases by 1 to 2 percent, which leads to a decrease in prices and an increase in urban and rural residents' food consumption. Compared with the baseline, in 2030, the consumption of fruits and aquatic products by urban and rural residents increase by 1.3 percent and 0.7 percent, respectively. Consumption of dairy products increases by 1.5 percent, and consumption of meat increases by 0.2 to 0.5 percent. In 2060, the trends in food consumption are the same as in 2030, and diet quality is significantly improved. In 2060, 4 percent of rural residents and 5.7 percent of urban residents experience an improvement in intake of nutritious foods (low bound score, LBS) (Figure 4-2).

The public investment in high-standard farmland has high return on investment, through enhancing grain productivity and promoting animal husbandry production with cheaper feed costs. At the same time, it also promotes the development of the agrifood system and the national economy through the linkages of the food supply chain. For each 1 yuan invested, the long-term investment returns on high-standard farmland construction are 2.2 yuan for agricultural GDP, 4.7 yuan for agrifood system GDP, and 10.8 yuan for economywide GDP (see Figure 4-2).

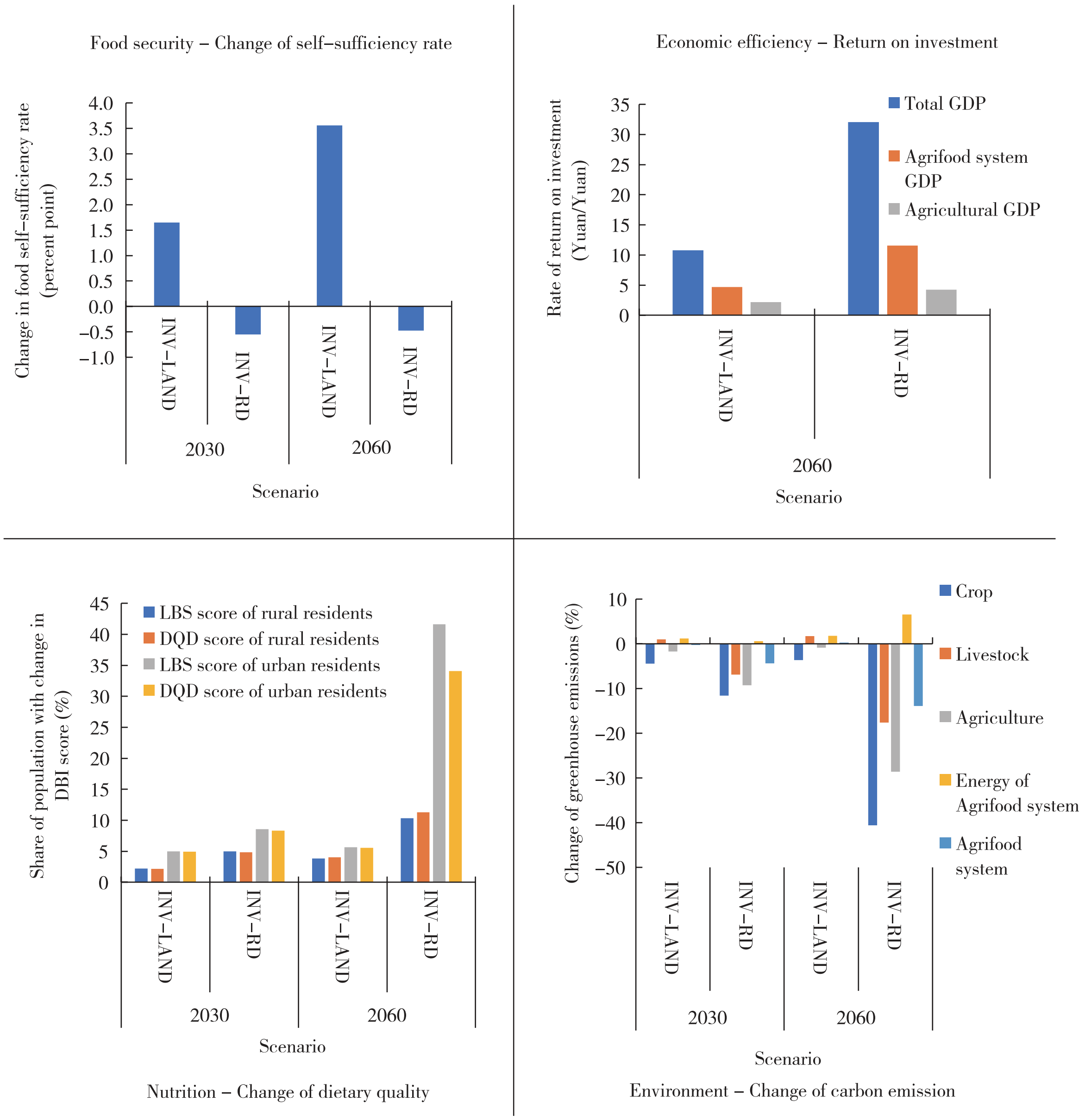
High-standard farmland construction is conducive to improving irrigation efficiency, saving water resources and fertilizer, and reducing carbon emissions. As fertilizer efficiency improves and fertilizer use decreases, carbon emissions decrease (see Figure 2). Compared with the baseline, in 2030, the GHG emissions from crop farming are down by 4.5 percent. However, the emissions from animal husbandry increase by 1.0 percent due to the increase in livestock production. As a result, the emissions from all agricultural activities decrease by 1.8 percent. In 2060, the emissions from crops decrease by 3.7 percent, and emissions of animal husbandry increase by 1.7 percent, and the emissions from all agricultural activities decrease by 0.8 percent.

Considering the uncertain impact development of high-standard farmland on yields and fertilizer use efficiency, high and low scenarios were also simulated, and the results are shown Table 4A1 in the appendix. Compared with the medium scenario described above, cereals output differs by 0.5 percentage points, and the price fluctuates by 3 percentage points under different scenarios. This results in a fluctuation of 5 percentage points in imports, a fluctuation in the food self-sufficiency rate by 0.5 percentage points, and a fluctuation in the food consumption of residents by 0.1 to 0.5 percentage points. The return on investment of agricultural GDP is between 1.5 and 3 yuan per 1 yuan invested, and the return on investment of total GDP will be between 7 and 15. The emissions from crop farming are reduced by 2.4 to 4.8 percent, and emissions from animal husbandry increase by 1.2 to 2.3 percent, and emissions from agriculture will be reduced by 0.6%-1.1%.

(2) Simulation results of public investment in green agricultural R&D and extension

To cope with the multiple challenges faced by the agrifood system, agricultural R&D and extension should not only focus on improving agricultural productivity, but also improve nutrition and increase green and low-carbon technology use. In Scenario 5, technology improvement and the increase of the feed conversion ratio, which reduces emissions from animal husbandry.

Figure 4-2 Impacts of Public Investment in Agriculture on Food Security, Nutrition and Environment – Compared with the Baseline



Source: Results are from the CAU-AFS model.

The simulation results show that when investment in green agricultural R&D and extension increase, agricultural productivity will be improved and the feed conversion ratio will increase, which leads to a reduction in the demand for feed grain, and a decrease in cereal prices, output, and imports, while the output of other agricultural products increases (see Table 4-3). Compared with the baseline, in 2030, the output of rice, wheat, and corn decreases by 5 to 7 percent, imports decrease by 13 to 14 percent, prices decrease by 4 percent, the output of fruit increases by 1 percent, and the output of pork, beef and mutton by 2 to 3 percent. In 2060, R&D and extension greatly increase the production capacity for agricultural products and output of important agricultural products increases significantly. Compared with the baseline, in 2060, the output of fruits and vegetables increase by 7 percent and 4 percent, respectively. The output of pork, beef, and mutton increase by 16 to 23 percent, and imports are reduced by 45 to 48 percent.

As shown in Table 4-3, technological progress broadly improves agricultural production capacity. Agricultural output increases, which results in the

Table 4-3 Impact of Public Investment in Agriculture on Food Supply and Demand–Compared with the Baseline (%)

Commodity	2030				2060				2030				2060			
	Scenario4 (INV-LAND): increase investment in high-standard farmland								Scenario 5 (INV-RD): increase investment in green agricultural R&D and extension							
	P	Q	M	C	P	Q	M	C	P	Q	M	C	P	Q	M	C
Rice	-10.3	1.4	-18.7	0.2	-12.9	2.6	-23.1	0.3	-3.8	-5.4	-13.2	0.1	-24.9	-12.6	-55.1	0.8
Wheat	-10.5	1.7	-19	0.2	-13	3.2	-22.9	0.3	-3.9	-6.8	-14.7	0.1	-25.1	-15.9	-57.1	0.8
Maize	-11.8	1.9	-21.1	0.2	-13.7	4.2	-23.4	0.3	-4.4	-4.6	-13.7	0.1	-26.7	-2.9	-52.5	0.7
Other grain	-10	4.2	-16	0.8	-12.5	9.6	-17.1	1.3	-0.9	-2	-4.6	0.1	-1.3	6.2	-5.9	0.8
Soybean	-10.5	20.7	-3.9	1.1	-11.6	25.8	-2.9	1.5	-1	3.3	0.4	0.3	-1.3	19	5.4	1.9
Fruits	-1.2	1.2	-1.8	1.3	-0.5	1.5	-0.9	1.1	-1.2	1	-2.3	1.6	-1.4	7.4	-5	6.1
Vegetables	-1.3	0.8	-2.2	0.7	-0.6	1.2	-1.2	0.6	-1.2	-0.1	-3.5	0.9	-1.5	4.1	-8.2	3.6
Pork	-2.4	0.8	-4.5	0.2	-1.8	1.5	-3.4	0.2	-6.4	1.8	-11.6	0.5	-29.7	16.3	-47.7	3.8
Beef	-2.2	1.1	-3.9	0.4	-1.5	1.8	-2.5	0.4	-6.3	2.4	-11	1	-29.7	22.9	-44.8	7.2
Mutton	-2.1	1	-3.7	0.4	-1.3	1.6	-2.3	0.3	-6.4	2.1	-11.3	1	-30.3	19	-47.4	7.1
Poultry	-2.9	0.8	-5.4	0.5	-3	1.4	-5.7	0.8	-6.2	1.6	-11.5	1.2	-27.9	12.9	-46.8	10
Dairy	-2.9	1.4	-4.9	1.5	-3.1	2.1	-5.3	2.2	-6.2	2.8	-10.3	3.1	-27.6	21.8	-41.9	24.2
Aquatic products	-1.7	1.4	-2.7	0.7	-1.4	1.9	-2.3	0.9	-2.1	1.9	-3.3	0.9	-5.4	10.8	-9.8	4.9

Source: Results are from the CAU-AFS model.

Note: P=Price, Q=Production, M=Import, C=Consumption.

generally decrease of prices. The food consumption of urban and rural residents increases due to the lower prices. Compared with the baseline scenario, in 2030, resident' consumption of fruits, vegetables, and dairy products increases by 1.6 percent, 0.9 percent, and 3.1 percent, respectively, and consumption of meat and aquatic products increases by 0.5 to 1.2 percent. Both production and consumption increase and prices fall further over time. Compared with the baseline, in 2060, residents' consumption of fruit, vegetables, and dairy products increases by 6 percent, 4 percent, and 24 percent, respectively, and the consumption of meat and aquatic products will increase by 4 to 7 percent. Diet quality improves significantly. In 2060, nutritious food consumption improves for 10.3 percent of rural residents and 33 percent of urban residents (low bound score, LBS) compared with the baseline (Figure 2).

The return on investment of green agricultural R&D and extension can both improve productivity and output for important agricultural products and promote the development of the agrifood system and the national economy through the agrifood system value chain. In the long term, the return on investment in green agricultural technology R&D and extension will be very high. Each 1 yuan invested will produce 4.2 yuan in benefits to agricultural GDP, 11.6 yuan for agrifood system GDP, and 32.1 yuan for total GDP (Figure 4-2).

Technological progress can decrease the GHG emission intensity and emissions from the agrifood system (Figure 4-2). Compared with the baseline, in 2030, emissions from crop farming and animal husbandry decrease by 12 percent and 7 percent, respectively. The carbon emissions of the agrifood system decrease by about 4 percent, equivalent to a reduction of 55.53 million tons of carbon dioxide emissions. In 2060, emissions from crop and animal husbandry decrease significantly, by 41 percent and 7 percent respectively. The emissions from agrifood systems decrease by about 14 percent, equivalent to a reduction of 136 million tons of carbon dioxide emissions.

In view of uncertainties about the effects of technological progress, the high scenario assumes that productivity of important agricultural products increases by 1.25 percent annually, with the aim of achieving a 30 percent reduction in emissions intensity and a 30 percent increase in feed conversion by 2060. In the low scenario, the productivity of important agricultural products is assumed to increase by 0.75 percent annually, and emissions intensity decreases by 20 percent and feed conversion increases by 20 percent by 2060. In the high and low scenarios, there are differences in food production, prices, imports, and household consumption, as shown in Table 4A-1 in Appendix. Compared with the medium scenario, cereal output in the high scenario varies by about 1 percentage point, and the cereal self-sufficiency rate differs by 0.2 to 0.3 percentage points. The return on investment of agricultural GDP will be between 3 and 5 yuan per 1 yuan invested, and the return on investment of the total GDP will be between 25 and 39. In terms of emissions, in 2030, in the high, medium, and low scenarios, the emissions reduction from crops is in the range of 9 to 14 percent, emissions from animal husbandry decrease by 5 to 9 percent, and emissions from the agrifood system decrease by 3 to 5 percent. In 2060, technological progress would have a larger impact on emissions reduction. Emissions from crops decrease by 33 to 48 percent, emissions from animal husbandry decrease by 14 to 22 percent, and emissions from agricultural activities decrease by 23 to 35 percent. Total carbon emissions from agrifood systems decrease by 11 to 17 percent.

4.6 Conclusion and recommendation

China's agricultural support policies should be reoriented to achieve multiple national goals in this new era. This chapter uses the CAU-AFS model to simulate and evaluate the comprehensive impacts of structural adjustments in agricultural support policy and public investment in agriculture on the agrifood system. The main conclusions are as follows:

First, China's agricultural producer subsidies have played an important role in ensuring food security. Simulation results show that removing producer subsidies for cereals would lead to a sharp rising of grain prices and a significant drop in grain production.

Second, the proper adjustment of producer subsidies for cereals to nutritious and low-carbon food will not only improve residents' diet quality but also reduce emissions, thus contributing to the transformation of the agrifood system for better nutrition, health, and green and low-carbon production.

Finally, public investment, including in high-standard farmland construction and green agricultural technology R&D, can promote the transformation of agrifood systems to achieve multiple goals. Development of high-standard farmland and green agricultural R&D and extension can not only increase production and household income, ensure food security, and increase the supply of important agricultural products, but also have a high economic investment return and reduce carbon emissions. In particular, the investment in green agricultural R&D and extension can reduce agricultural emissions by nearly 30 percent.

Based on these findings, the following policy recommendations are offered:

First, in order to achieve the strategic goals of healthy China, ecological sustainability, and rural revitalization, a comprehensive evaluation of the impact and trade-offs entailed by agricultural support policies for food security, economic benefits, nutritional health, green and low-carbon production is needed to optimize future agricultural support policies.

Second, agricultural production subsidy policies should be appropriately adjusted to support nutritious and low-carbon food, which is conducive improving residents' diets, promoting residents' nutritional health, and reducing carbon emissions.

Finally, the existing agricultural support policies are insufficient to achieve the nation's multiple goals. Support from agricultural policies, including support for nutritious and low-carbon foods, development of high-standard farmland, R&D and extension for green agricultural technology, and other public investments should be increased. Such agricultural support policies can help transform the current agrifood system into a nutritious, healthy, green, and low-carbon agrifood system.

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Appendix Table 4A-1 Uncertainty Analysis of the Comprehensive Impacts of Public Investment Policies in Agriculture on Food Security, Nutrition, and the Environment

	High-standard farmland construction						Green agricultural R&D and extension					
	2030			2060			2030			2060		
	Low	Me-dium	High	Low	Me-dium	High	Low	Me-dium	High	Low	Me-dium	High
Food security (Change in food self-sufficiency rate) (percent point)												
Change in food self-sufficiency rate	1.1	1.6	2.1	2.4	3.6	4.6	-0.4	-0.5	-0.7	-0.3	-0.5	-0.8
Economy (GDP change rate) (%)												
Total GDP	—	—	—	6.9	10.8	14.5	—	—	—	24.6	32.1	39.2
Agrifood systems GDP	—	—	—	3.2	4.7	6.1	—	—	—	9.0	11.6	14.1
Agricultural GDP	—	—	—	1.5	2.2	2.9	—	—	—	3.3	4.2	5.1
Diet (Share of population with change in DBI score) (%)												
Rural residents' LBS	2.3	2.2	4.2	2.5	3.9	5.5	4.1	5.0	6.4	9.7	10.3	14.6
Rural residents' DQD	2.2	2.2	4.0	2.5	4.0	5.3	4.0	4.8	6.1	9.0	11.3	13.2
Urban residents' LBS	5.0	5.0	9.8	5.7	5.7	11.0	7.4	8.6	11.9	35.2	41.6	51.0
Urban residents' DQD	5.0	4.9	9.5	5.6	5.5	10.5	7.2	8.4	11.5	29.8	34.1	40.0
Environment (Greenhouse gas emission change rate) (%)												
Crop	-3.0	-4.5	-5.9	-2.4	-3.7	-4.8	-9.0	-11.6	-14.3	-32.8	-40.6	-48.0
Livestock	0.7	1.0	1.3	1.2	1.7	2.3	-5.4	-6.9	-8.6	-13.7	-17.6	-22.2
Agriculture	-1.2	-1.8	-2.3	-0.6	-0.8	-1.1	-7.2	-9.3	-11.5	-22.8	-28.6	-34.6
Energy of agrifood systems	0.8	1.2	1.6	1.2	1.8	2.3	0.4	0.6	0.7	5.1	6.5	7.9
Agrifood systems in total	-0.2	-0.3	-0.4	0.2	0.2	0.3	-3.4	-4.4	-5.4	-11.1	-13.9	-16.8

Source: Results are from the CAU-AFS model.

Chapter 5

China's Fiscal Expenditure on Agriculture: Impact on the Urban–Rural Income Gap

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Key Findings

● Since the reform and opening-up, China's highly centralized fiscal system of agricultural support has been decentralized. Sustained increases and structural improvements in fiscal expenditure on agriculture have been witnessed over the past three decades, especially since the "Coordinated Urban–Rural Development" strategy in 2003. Within the fiscal expenditure on agriculture, agricultural production and rural construction support currently account for the greatest shares. The share of agricultural production is particularly high in the predominantly agricultural provinces.

● Fiscal expenditure on agriculture reduces the per capita income gap between urban and rural residents. A 10% increase in the fiscal expenditure on agriculture leads to a decline in the urban–rural income ratio by about 1% of the standard deviation. Greater effects are observed in the underdeveloped provinces. Relative to the other categories of fiscal expenditure on agriculture, those on agricultural production and poverty alleviation exhibit more substantial effects.

● Fiscal expenditure on agriculture reduces the urban–rural income gap through three main channels: stimulus to rural income, accelerated rural labor reallocation to non-agricultural sectors, and promotion of integration between agriculture and other industries.

● As a province with one of the lowest urban–rural income gaps in China, Zhejiang's fiscal system of agriculture support exhibits three remarkable characteristics. These include more local funds in addition to the central government's expenditure, greater expenditure directed toward sustainable growth, and effective leverage of social capital. In addition, Zhejiang has adopted a series of innovative agricultural support measures, such as the Cooperation between Mountainous and Coastal Areas and the Green Rural Revival Program. The analysis of Zhejiang thus provides valuable lessons for other parts of the country.

Policy Recommendations

● The expenditure structure and spatial distribution of the central government's fiscal expenditure on agriculture should be improved. Support for the less-developed regions and important affairs such as agricultural production, rural construction, and poverty alleviation should be enhanced. A redistribution system with reward and punishment must be explored to establish a supervision mechanism for effective fiscal transfers based on the efficiency of fund use.

● Local governments should be encouraged to tailor the system of fiscal expenditure on agriculture to fit local contexts. More incentives should be provided to developed areas for sustainable rural development. Greater efforts need to be made to strengthen the linkages between the Rural Revitalization Strategy and food security and poverty alleviation in less-developed and major grain-producing areas. The fiscal system should play a significant role in developing a diversified investment pattern of agriculture support.

● Policy coordination between fiscal expenditure on agriculture and other policies should be reinforced to jointly promote integrated urban–rural development. Strengthening the labor reallocation channel of fiscal expenditure by urging industrial relocation to counties and improving policies to support rural migrants in cities is essential. The integration between agriculture and other industries' channels of fiscal expenditure should be boosted by unblocking urban–rural factor flows and the rural innovation and entrepreneurship environment improved.

5.1 Introduction

Since the reform and opening-up in 1978, China's income distribution gap has widened. The Gini coefficient of national residents' income rose from 0.31 in 1981 to a historic high of 0.49 in 2008 and has continued to hover at a high of 0.46 in the recent years (Molero-Simarro, 2017; Li and Zhu, 2018; Luo et al., 2021). Narrowing the income gap between urban and rural residents is the key to reducing China's Gini coefficient. The ratio of per capita income between urban and rural residents exhibited an overall growth trend before 2009, despite the increase in disposable income per capita of rural residents from 134 yuan in 1978 to 18,931 yuan in 2021. In 2007, the urban–rural income ratio exceeded 3:1 for the first time and contributed over 50% to the Gini coefficient of the national income distribution (Li and Wan, 2013). Since 2009, the urban–rural income gap has decreased; however, the decline has nearly halted post 2014. In 2021, the urban–rural income ratio was still as high as 2.5:1, almost equal to that in 1978 and larger than that in developed countries, which have a level of approximately 1:1 or lower.

Shortcomings in the efficiency and competitiveness of agriculture are the main obstacles to narrowing China's urban–rural income gap. The food system transformation plays a key role in compensating for these limitations. Therefore, China has adhered to the policy of prioritizing the development of agriculture and rural areas by successively implementing many comprehensive approaches, including the agriculture supply-side structural reform, Rural Revitalization Strategy, and modernization of agriculture in rural areas. Moreover, the central government's vision of the urban–rural relationship has also gradually shifted from "Coordinated Urban–Rural Development" to "Urban–Rural Integration" and eventually to "Integrated Urban and Rural Development." This evolution demonstrates the deepening of the government's understanding of pathways to support agriculture and rural development. In contrast to the emphasis on the central government's overall planning status, as reflected in "Coordinated Urban–Rural Development" and the target-clearing purpose of "Urban–Rural Integration," the current mission of "Integrated Urban and Rural Development" identifies the establishment of fundamental institutions that facilitate an overarching integration between urban and rural areas as the key approach to promoting agricultural and rural development. In 2021, China's goals transitioned from becoming a moderately prosperous society to emerging as a modern country by 2050, thereby aiming at promoting common prosperity for all people. As a key component of institutions for urban–rural integrated growth, fiscal expenditure on agriculture has remained an effective measure to narrow the urban–rural income gap. Thus, it serves as an important approach to achieving common prosperity.

In the past four decades, China has transformed a highly centralized system of fiscal expenditure on agriculture into a decentralized model, with stronger and more precise targeting measures adopted to enhance the effectiveness of fiscal support. Consequently, there have been notable achievements in rural development, ranging from reducing poverty by approximately 770 million people to the radical leap forward of agricultural modernization, with the contribution rate of science and technology progress exceeding 58%. The experience holds valuable insights for the world at large and developing countries in particular, given the increasing recognition of agricultural and rural development as persistent global challenges in light of the recent pandemic and international conflict. In fact, 7 of the 17 United Nations Sustainable Development Goals are immediately related to agriculture and rural development (FAO, 2022), with 3 (i.e., no poverty, zero hunger, and responsible consumption and production) relying particularly on the food system transformation. China's lessons highlight that the government is an irreplaceable actor in promoting rural development and food system transformation. Accordingly, it must adopt continuous fiscal reforms and innovative policy tools beyond its conventional role to sequentially outline the pursuit of an overall transition across time and space.

5.2 The system of China's fiscal expenditure on agriculture and its evolution

China's fiscal expenditure on agriculture includes support for agricultural production and rural residents' livelihood and expenditure to improve rural governance, public services, and infrastructure (Yu et al., 2015; Zhou and Yan, 2019). The statistical definition of fiscal expenditure on agriculture was adjusted in 2007 according to China's National Bureau of Statistics (NBS). Prior to that, it included: (1) expenses to support the production of various rural industries and operational expenses of official departments related to agriculture, forestry, water conservancy, and meteorology; (2) rural infrastructure expenses; (3) agricultural science and technology expenses; and (4) poverty, disaster, and other relief expenses. Since 2007, the fiscal expenditure on agriculture is no longer reported as an individual category. Instead, it is included in the new group named "Expenses on Agriculture, Forestry and Water Conservancy," which includes 10 expenditure items, such as agriculture expenses, forestry expenses, water conservancy expenses, expenses on the South-to-North Water Diversion Project, poverty alleviation funds, and expenses on comprehensive agricultural development and rural reforms (Liu, 2008; Research group on China's agricultural domestic support et al., 2013; Wang and Liu, 2015; Zhong et al., 2018). Although some expenses may not be completely directed toward the agricultural and rural sectors (Liu, 2000), we define all items in the "Expenses on Agriculture, Forestry and Water Conservancy" group as fiscal expenditure on agriculture, as distinguishing between funds' directions based on China's statistical data is impossible. Moreover, even expenses not directed toward agriculture are fundamental to ease the overall environment and resource constraints that the agricultural sector faces.

Since the reform and opening-up, China's system of fiscal expenditure on agriculture has undergone three stages of development. The first stage was from 1979 to 1993; with comprehensive agricultural production, operation, and distribution system reforms, China overturned its weak agricultural production growth and unraveled the dual structure between urban and rural areas. Meanwhile, the highly centralized fiscal expenditure system on agriculture adopted during the planned economy phase was transformed into a decentralized model featuring increased local management. In addition, many incentive measures, such as establishing agricultural development funds, improving medium and low-yield fields, subsidizing production inputs, and reducing agricultural taxes were considered to revitalize agricultural production.

The second stage ranged from 1994 to 2002. The tax-sharing reform initiated in 1994 laid a solid foundation for the subsequent formation of a modern system of fiscal expenditure on agriculture resting on the public finance management framework, as observed in most developed economies. China's central government strengthened its fiscal power and reclaimed most fiscal responsibilities to support agricultural and rural development. The structure of fiscal expenditure on agriculture also changed. Expenses on food security, agricultural science and technology advancement, poverty alleviation, and environmental protection gradually accounted for noteworthy shares in fiscal support to agriculture. Despite such remarkable reforms, China's overall fiscal system became increasingly urban-biased in this stage. Consequently, the share of fiscal expenditure on agriculture showed a downward trend.

The third stage, since 2003, has aimed at achieving more balanced development between urban and rural sectors through fiscal expenditure on agriculture. In this stage, China successively presented strategies of "Coordinated Urban–Rural Development," "Urban–Rural Integration," and "Integrated Urban and Rural Development" to echo the Communist Party of China's (CPC) long-term priority of addressing agricultural, rural, and farmer problems, adhering to a guideline of "giving more, taking less, and letting loose (i.e., duoyu, shaoqu, fanghuo)." The most notable manifestation of this methodology in fiscal policies in agriculture was in the implementation of "four reductions or exemptions" (i.e., reducing or exempting taxes on agriculture, husbandry, agricultural specialty, and slaughter industries) and "four subsidies (i.e., subsidies to grain production, agricultural materials, improved crop seeds, and agricultural machinery)." Since the new socialist countryside construction movement initiated in 2005, the coverage of fiscal support for agriculture has further expanded to include rural infrastructure, social security, environmental protection, and agricultural price support. The effectiveness of the fiscal system in strengthening agriculture and benefiting farmers has been considerably improved.

Following the Rural Revitalization Strategy proposal in the 19th National Congress of the CPC in 2017, China's fiscal expenditure was directed toward accomplishing the establishment of an overall well-off society and paving the way for the country's development goals by

2050. Expenses on poverty alleviation, rural education, infrastructure, and environmental protection were boosted, leading to historically unprecedented levels of agricultural support in the total fiscal expenditure. Moreover, innovative support measures such as the establishment of special purpose and rural industry development funds, issue of subsidized microfinance loans for poverty alleviation, expansion of government purchasing services, and cooperation with social capital led to notable improvements in the efficiency and management of the fiscal expenditure on agriculture.

As shown in Figure 5-1, the increasing fiscal expenditure on agriculture was generally associated with smaller urban–rural income gaps during the second and third development stages of the system of fiscal expenditure on agriculture. Owing to the urban-biased fiscal policy, the share of agricultural support in the total fiscal expenditure experienced an overall drop from 1994 to 2002, even as the urban–rural income ratio rapidly increased. In contrast, during the two decades since 2003, the fiscal expenditure on agriculture has increased by approximately 17 times, with the central government's successive promotion of rural tax reforms, new socialist countryside construction, poverty alleviation, and the Rural Revitalization Strategy. The share of agricultural support in the total fiscal expenditure has remained above 9% since 2009.

Consequently, the urban–rural income ratio has

Figure 5-1 Fiscal Expenditure on Agriculture and Urban-rural Income Ratio of China, 1978-2020

Source: China Statistical Yearbooks (1981-2020).

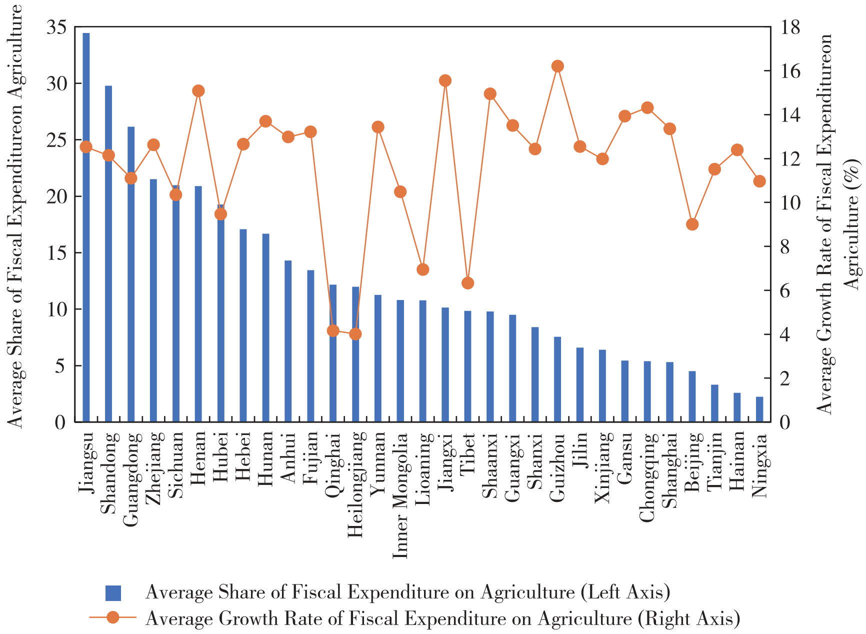
Note: Fiscal expenditure on agriculture includes expenses by both the central and local governments. The expenditure in 2007 is rescaled by assuming that the growth rate from 2006 is the average of growth rates between 2005-2006 and 2007-2008 and the expenditure afterwards is accordingly adjusted with this ratio, to accommodate changes of the statistical definition.

decreased since 2009 after a brief high. However, the fiscal expenditure on agriculture and urban–rural income gap moved in the same direction prior to the 1994 tax-sharing reform. A possible explanation is that in the fiscal contract system of that period, support to agricultural production and rural residents was bundled with the responsibilities of local governments or even township and village enterprises (TVEs) rather than central responsibility, as local governments can obtain considerable extra-budgetary fiscal revenue through the TVEs (Lan, 2021).

Although China has strengthened fiscal support for agriculture, especially since 2003, considerable differences exist across regions. As subnational fiscal expenditure data are not available prior to the tax-sharing reform, we focus on the post-1994 period for inter-provincial comparisons[1] . As shown in Figure 5-2,

[1]The provincial-level regions in this chapter are the provincial-level administrative regions (provinces, provincial-level municipalities, and autonomous regions) in mainland China, excluding Hong Kong, Macao and Taiwan of China.

Figure 5-2 **Fiscal Expenditure on Agriculture Across Provinces, 1994-2020**



Source: China Statistical Yearbooks (1994-2020).

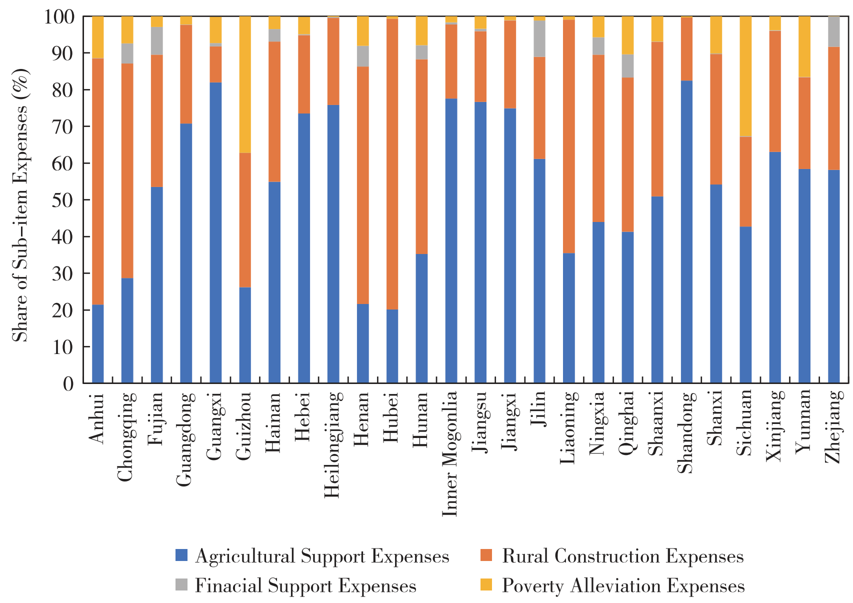
the share of agricultural support in fiscal expenditure was relatively higher in the main agricultural provinces. The shares of Jiangsu, Shandong, Guangdong, Sichuan, and Henan provinces all exceeded 20% on average between 1994–2020. The growth rate of fiscal expenditure on agriculture was relatively greater in the major grain-producing areas. The average growth rate exceeded 15% in Jilin, Jiangxi, and Henan provinces.

There are also substantial regional differences in the structure of fiscal expenditure on agriculture. Among the 10 expenditure items within the "Expenses on Agriculture, Forestry and Water Conservancy" group collectively defined as fiscal expenditure on agriculture, the shares of agricultural and water conservancy expenses in terms of the amount exceeded 20% each and were considered primary expenditure items. In contrast, the expenditure shares of rural inclusive finance and target price subsidies remained below 2%. For the ease of exposition of the fiscal expenditure structure, we classify the items within the "Expenses on Agriculture, Forestry and Water Conservancy" group into four categories: The first category, "agricultural support expenses," incorporates agriculture expenses, forestry expenses, target price subsidies, and other direct or indirect support to agricultural production and operation. The second category, "rural construction expenses," includes the expenditure on water conservancy, the South-to-North Water Diversion Project, comprehensive agricultural development, and rural reforms, and other items related to improving agricultural conditions and rural infrastructure. As public facilities and agriculture and rural area services constitute major expenses categorized under "miscellaneous expenses on agriculture, forestry and water conservancy," the entire miscellaneous expense item is included as a component of "rural construction expenses" as well. [2] The third category, "financial support expenses," comprises two expenditure items, the development of inclusive finance and the promotion of financial support for agriculture. The final category, "poverty alleviation expenses," includes a single expenditure item, the special fiscal fund for poverty alleviation, which was initiated following the targeted poverty alleviation proposal in the 18th National Congress of the CPC.

In line with data availability on province-level disaggregated fiscal expenses, Figure 5-3 shows the average structure of fiscal expenditure on agriculture

[2] The main expenditure items in other agricultural, forestry and water expenditure include four items: special funds for the Construction of New Socialist Countryside, funds for agricultural structure adjustment and expenditure for dissolving other public welfare rural debts and other expenditure.

Figure 5-3 **The Average Structure of Fiscal Expenditure on Agriculture Across Provinces, 2012-2020**



Source: Final Statements of General Public Budget Expenditure of Provinces (2012-2020).

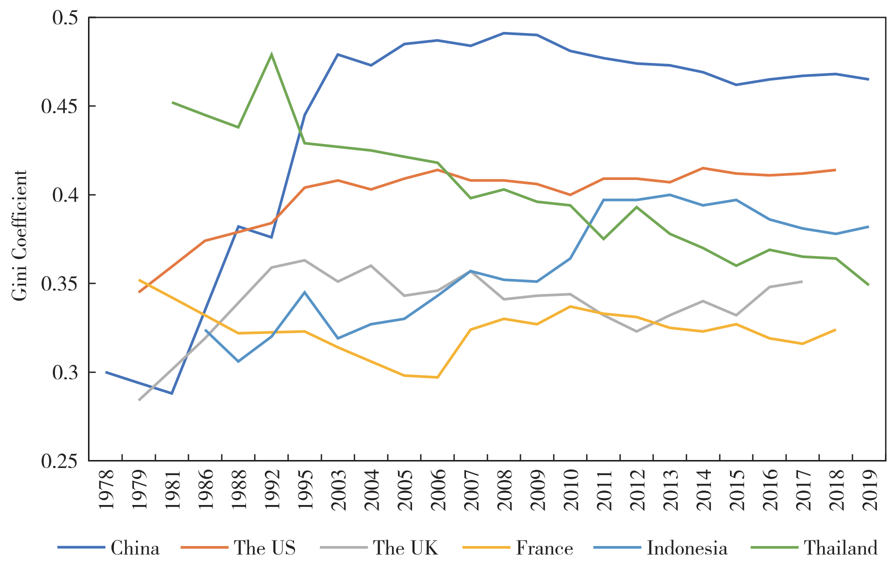
for each province since 2012. Agricultural support and rural construction expenses constituted the bulk of fiscal expenditure on agriculture in all provinces except Guizhou and Sichuan. In the main agricultural provinces like Heilongjiang, Guangxi, Hebei, Inner Mongolia, Jiangxi, Shandong, Jiangsu, and Guangdong, agricultural support expenses were the greatest and exceeded 70% on average. The share of rural construction expenses was the greatest in Hunan, Hubei, and Henan, because of their contribution to the South-to-North Water Diversion Project, and in Anhui and Liaoning, for harnessing the Huai and Liao Rivers. The share of rural construction expenses was also notable in the four province-level municipalities. In contrast, poverty alleviation expenses accounted for the largest and second-largest shares of fiscal expenditure on agriculture in the two major battlefields of poverty alleviation, i.e., Guizhou and Sichuan. The share was also noted in Tibet; however, the share of financial support expenses remained small in every province.

5.3 Narrowing the urban–rural income gap: impact and mechanisms of fiscal expenditure on agriculture

China's income distribution has deteriorated since the reform and opening-up. Based on Figure 5-4, China's Gini coefficient of income distribution remained at or even below 0.3 during the initial reform and opening-up period, a low figure compared to that of most developed economies like the United States (US), the United Kingdom (UK), and France and emerging ones like Indonesia and Thailand. The Gini coefficient skyrocketed after the mid-1980s and reached 0.479 in 2003, a value much higher than that for the other economies listed above. As urban–rural inequality majorly contributed to the unequal income distribution, the CPC's 16th National Congress proposed the strategy of "Coordinated Urban–Rural Development." Consequently, China's income distribution Gini coefficient gradually plateaued and began to decline after 2008 from its peak of 0.491, a 70.5% increase from the 1981 level. Despite the decline, China's Gini coefficient today is still remarkably higher than that of other countries.

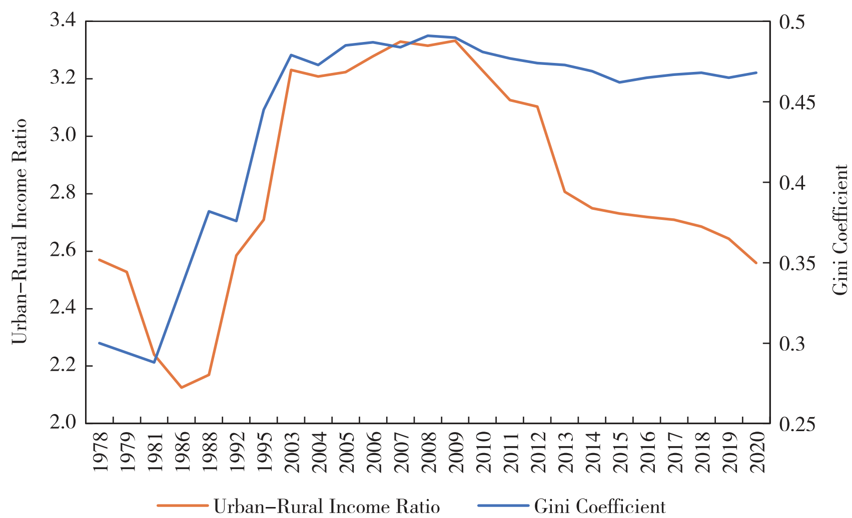
The urban–rural income gap is a critical driver of China's Gini coefficient of income distribution (Luo et al., 2020). According to Figure 5-5, the Gini coefficient followed the same trend as the urban–rural income ratio. Between the mid-1980s and the early 21st century, the Gini coefficient rapidly rose, accompanied by a continuous expansion of the urban–rural income ratio. In 2008, the Gini coefficient declined, with a simultaneous

Figure 5-4 Gini Coefficients of China and Major Developed and Emerging Economies, 1978-2020



Source: Data for China respectively come from Lu (2012) for the year of 1978, the World Bank for 1981 and 1992, the Chinese Academy of Social Sciences for 1988 and 1995, and the NBS since 2003. Data for other countries come from the World Bank.

Figure 5-5 China's Gini Coefficient and Urban-rural Income Gap, 1978-2020



Source: The Gini coefficient data respectively come from Lu (2012) for the year of 1978, the World Bank for 1981 and 1992, the Chinese Academy of Social Sciences for 1988 and 1995, and the NBS since 2003. The urban-rural income gap data comes from China Statistical Yearbook (1981-2020).

reduction in the urban-rural income ratio. Decomposition analyses of China's Gini coefficient also highlight the urban-rural income gap's contribution, which exceeded 40% in 1995 (Sicular et al., 2008) and surpassed 60% in 2009 (Luo, 2017). The urban-rural income gap remained the biggest contributor to unequal income distribution despite a remarkably narrowing trend (Li and Wan, 2013; Luo, 2017).

China's urban-rural income gap reflects development regularities around the world and stems from the institutional background of the country's socio-economic context. On the one hand, most countries experienced broader urban-rural income gaps during economic transformation, especially in the industrialization and urbanization stages (Glaeser and Mare, 2001; Zhang, 2004; Young, 2013; Baymul and

Sen, 2019). China's urban–rural income diversion period also overlapped with these stages following successive market reforms. With industrialization, the labor income share in the economy is often reduced because the labor share is usually the lowest in the secondary sector (Mao and Yao, 2012; Bai, 2015; Liu et al., 2018). In the case of China, the labor income share in the gross domestic product (GDP) decreased by 10 percentage points between 1995 and 2005. Consequently, the economic growth of the urban sector with relatively higher capital intensity exceeded that of the rural sector, leading to a wider urban–rural income gap.

On the other hand, China's urban–rural imbalances are unique compared to countries with a much larger scale, more rapid deterioration, and greater inter-regional differences and are intertwined with critical social and environmental imbalance issues (Mao and Lin, 2022). Three aspects of China's institutional background can explain such uniqueness. First, the urban–rural dual system that China established in the planned economy created prolonged institutional barriers to coordinating urban and rural growth. Second, after the reform and opening-up, China's export-oriented growth rested heavily on the competitive advantage of low costs, which hindered transformation toward intensive growth. Third, many structural problems remain unresolved in the agricultural sector, with production efficiency and product quality both persisting as bottlenecks to farmers' income growth.

The current study explains the evolution of China's urban–rural income gap from two perspectives. The first explanation is the urban–rural dual system. In the commodity market, the system primarily manifested as price scissors between agricultural and industrial goods brought about by the unified purchase and sale framework, which led to the agricultural sector subsidizing the industrial sector and widened the urban–rural income gap (Knight, 1995; Oi, 1999; Lin and Yu, 2008; Liu et al., 2017). In the factor market, the dual system of labor emerged fully as the household registration system and urban–rural division of social security and public services, which resulted in a distorted spatial distribution of the labor force and unequal labor incomes (Cai, 2002; Liu; 2005; Cai, 2011; Zhang and Chen, 2011; Wan and Li 2013; Song, 2014). Separated urban and rural land markets characterized the dual system on land. Though the land urbanization rate was once faster than that of population urbanization, as local governments pursue fiscal revenues from selling rural land, rural residents found it difficult to obtain benefits from land appreciation because of the segregated land market (Cheng and Sekden, 1994; Luo, 2010; Xie, 2017; Wang et al., 2019; Chen et al., 2020). Similarly, the dual capital system has resulted in an astounding mismatch of allocation across regions (Mao, 2012). Owing to sluggish rural financial reforms, sustained rural capital flows to the more capital-intensive urban sector enlarged the rural production capital gap, further aggravating the urban–rural income divide (Vendryes, 2010; Wang et al., 2014; Zhou et al., 2015; Zhong et al., 2020).

The second explanation of China's urban–rural income gap focuses on economic structures. Some studies specifically focused on the reform of state-owned enterprises (SOEs). On the one hand, SOE reform increases the demand for rural surplus labor and narrows the urban–rural income gap (Zhang, 2019). On the other hand, the private sector typically entails an unequal income distribution compared to that of SOEs, potentially widening the urban–rural income gap instead (Chen and Lin, 2013). Other studies have highlighted the structural changes because of opening-up. As China's comparative advantage primarily lies in labor-intensive manufacturing industries, opening up trade benefited manufacturing workers (Mao and Zhang, 2013). However, because of barriers to urban–rural labor movements and the skill threshold of manufacturing industries, a limited portion of rural residents joined the trade sector, and the urban–rural income gap continued to increase (Hu, 2002; Anderson, 2005; Goldberg and Pavcnik, 2007; Wei and Zhao, 2012).

In addition to these two perspectives, fiscal policy has often been considered critical for understanding China's urban–rural income gap. Several empirical studies have revealed a negative relationship between fiscal expenses and the urban–rural income ratio, as, for a long time, China's fiscal system remained heavily urban-biased (Lu and Chen, 2004; Gao et al., 2013; Zhao and Xu, 2013). However, the effects differ across fiscal expenditure categories. Kanbur et al. (2021) found that the agricultural tax exemption and fiscal support to the new socialist countryside construction movement narrowed the urban–rural income gap. Agricultural subsidies on production and machinery purchases as well as infrastructure expenses facilitate agricultural productivity growth and rural labor reallocation, which could lower the urban–rural income gap (Fan et al., 2000; Li and Qian, 2004; Shen and Zhang, 2007; Lu et al., 2015; Gong, 2018). The fiscal expenditure on rural finance boosted agriculture specialization and industrial integration, which was also beneficial in narrowing the income gap (Ma et al., 2020; Zhang and Zhou, 2021). Finally, the targeted poverty alleviation policy since the 18th CPC National Congress has also influenced low-income farmers' income growth (Liu et al., 2018; Cheng et al., 2021). Nevertheless, the literature has not investigated the overall impact on the urban–rural income gap of fiscal expenditure on agriculture nor distinguished between the differential impacts across expenditure categories with a systematic comparison. Moreover, the mechanisms underlying the impacts of fiscal expenditure on agriculture have also not been sufficiently explored.

5.3.1 Benchmark regression

We construct the following benchmark empirical model for China's province-level panel data to examine the impact of fiscal expenditure on agriculture on the urban–rural income gap. Using the subscripts i and t for provinces and years, respectively, our model is specified as follows:

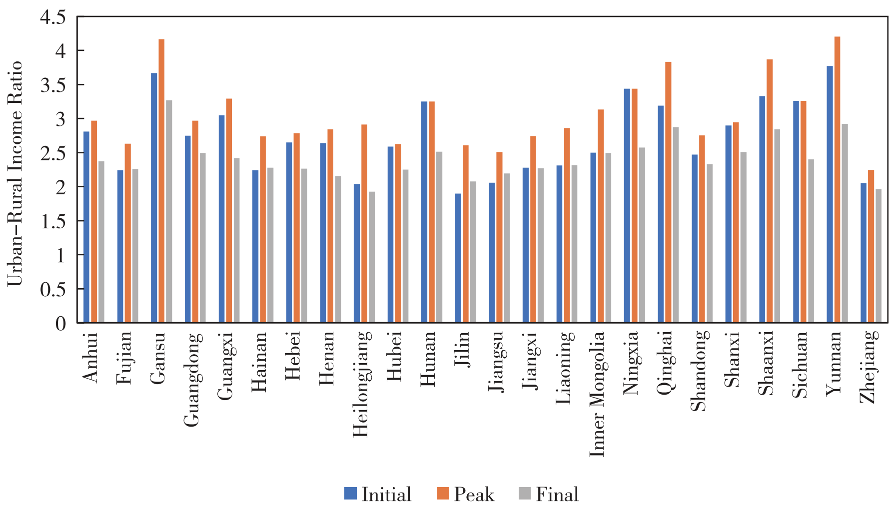
$$Gap_{it}=C+\alpha\ ln(expenditure_{it})+\gamma\ X_{it}+\mu_i+u_{it} \qquad (5.1)$$

In Equation (5.1), the explanatory variable Gap_{it} is the urban–rural income ratio. The ratio is calculated using the per capita disposable income of urban residents and per capita net income of rural residents before 2013 and the disposable income of urban and rural residents after 2013 owing to an adjustment in the NBS definition of rural income. To ensure the comparability of the ratio over time, we rescale the ratios calculated for before 2013 by assuming that the growth of this ratio remained the same in 2013 under both old and new definitions. Using the NBS data, Figure 5-6 illustrates the evolution of the urban–rural income ratio of each province since 1985, when the per capita income data became available. An inverted U-shaped evolution of the urban–rural income ratio emerges for all provinces. The peak indicated by orange bars and the end-of-period level indicated by gray bars are generally higher for the western regions.

In line with existing studies (Li and Qian, 2004; Xiao and Xiao, 2013; Luo and Jiao, 2014; Lu et al., 2015), $ln(expenditure_{it})$ is the log of the variable of interest, i.e., fiscal expenditure on agriculture, in Equation (5.1). The fiscal expenditure data are drawn from the NBS but adjusted for changes in the statistical definition since 2007, as mentioned in Section 5.1. Specifically, we assume that the growth of fiscal expenditure on agriculture in 2007 from the previous year is the average of the 2006 and 2008 growth rates.

In Equation (5.1), X_{it} is a set of control variables that incorporate alternative explanations of the urban–rural income gap in the literature. Specifically, we

Figure 5-6 Initial, Peak and Final Urban-rural Income Gap of Chinese Provinces, 1985-2020



Source: Statistical Yearbooks of each province (1985-2020).

introduce the logarithm of per capita GDP to measure marketization as a general indicator of the dual system (Fan et al., 2003) and control its square term for possible nonlinear relationships (Lu and Chen, 2004). We include the employment share of SOEs (Chen and Lin, 2013) and trade openness denoted by the ratio of total imports and exports to the GDP (Wei and Zhao, 2012) to reflect the two key aspects of economic structures. Finally, we control the share of total fiscal expenditure in the GDP for any prospective urban bias in the overall fiscal system (Lu and Chen, 2004). The data for these variables have been taken from the NBS statistical yearbooks and provinces and labor statistical yearbooks. In the equation, μ_i denotes province-level fixed effects, and u_it is the usual residual term.

We investigate the robustness of the estimates in Equation (5.1) in two aspects. First, the key variable is replaced by the share of agriculture support in total fiscal expenditure to check if the results are robust when the force of fiscal support is measured by intensity rather than scale. Second, we alleviate the concern of endogeneity in fiscal expenditure—greater agricultural support may be offered to provinces with larger urban–rural income gaps—by introducing the lag income gap and re-estimating the following model using a dynamic panel approach:

$$Gap_{it}=C+\alpha\ln(expenditure_{it})+\beta Gap_{it-1}+\gamma X_{it}+\mu_i+u_{it} \quad (5.2)$$

System generalized method of moments (GMM) estimators are derived from Equation (5.2) with two and longer period lags of the explained and endogenous variables, and all lags of exogenous variables serve as instruments.

Table 5-1 reports the estimation results of Equations (5.1) and (5.2) for 1994–2020 based on data availability. The four province-level municipalities and Tibet are excluded following the usual procedure in the literature.[3] Column (1) presents a significantly negative coefficient for $\ln(expenditure_{it})$, suggesting that increased fiscal expenditure on agriculture could reduce the urban–rural income gap. Specifically, with 10% more fiscal expenditure, the income gap would decline by 0.0055, approximately 1.09% of its standard deviation (Appendix Table 5A). From 1994 to 2020, China's fiscal expenditure on agriculture increased 45 times. This implies that without considering changes in the other factors influencing the urban–rural income ratio, the ratio would decline by 0.2 if driven by the fiscal expenditure on agriculture alone.[4]In Column (2), the fiscal expenditure amount is replaced by the share of agricultural support in total fiscal expenditure. The estimated coefficient for this intensity measure is also significantly negative. In Column (3), the significance and sign of the coefficient are again confirmed in the dynamic panel model. However, its magnitude is 2.5 times that in Column (1). This may be attributable to the abnormal enlargement of coefficient magnitudes typically found in instrumented estimations (Jiang, 2017). To identify the reasonable impact of fiscal expenditure, we follow the fixed effects model below, as its estimation results are robust.

Columns (4)–(6) of Table 5-1 compare the estimation results across periods and regions. The fourth

Table 5.1 Benchmark Estimation of Effect of Fiscal Expenditure for Agriculture on Urban–rural Income Gap

	(1)	(2)	(3)	(4)	(5)	(6)
ln（expenditure）	-0.0550* (0.0312)		-0.137*** (0.0515)	-0.092*** (0.0351)	-0.0813** (0.0341)	-0.335*** (0.0594)
Agricultural supports/total fiscal expenditure,%		-0.00595*** (0.00177)				
Provinces	All	All	All	All	With poverty counties	Within WDP
Period	1994-2020	1994-2020	1994-2020	2013-2020	1994-2020	1994-2020
Model	FE	FE	GMM	FE	FE	FE

Note: Standard errors in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10%.

[3]Lu and Chen (2004) drop province-level municipalities' and Tibet's samples because of outlier and omitted problems.

[4]0.2=ln45×0.055

column shows that the impact of fiscal expenditure on agriculture has been strengthened since 2012 with the implementation of targeted poverty alleviation. With a 10% increase in fiscal expenditure, the urban–rural income ratio declines by 0.0092, a change 67.4% larger than that indicated in Column (1). The other two columns show that the impact of fiscal expenditure is also more notable in less-developed areas, which are respectively represented by provinces with poverty-stricken counties in Column (5) and by those classified under the Western Development Program (WDP) in Column (6). Taking provinces in the WDP as an example, 10% more fiscal expenditure on agriculture reduces the urban–rural income gap by 0.0335, which is about six times the average effect considering all provinces.

5.3.2 Heterogeneities across fiscal expenditure categories

The fiscal expenditure on agriculture includes four main categories, as discussed in Section 5.1. To investigate heterogeneities in the impact on urban–rural income ratio across expenditure categories, we introduce interaction terms between $\ln(\text{expenditure}_{it})$ and the share of each category in the total fiscal expenditure on agriculture into Equation (5.1). As the sum of the shares of categories equals 1, we use the category of poverty alleviation expenses as the benchmark to avoid perfect collinearity. Table 5-2 presents the estimation results. Column (1) shows that the coefficient for $\ln(\text{expenditure}_{it})$ remains significantly negative. Among the coefficients before interaction terms, only that for the category of agricultural support expenses is significant despite all negative signs. This indicates that for a given amount of fiscal expenditure on agriculture, a greater share of agricultural support expenses tends to increase the impact on the urban–rural income gap. With a 1 percentage point increase in this share, the effect of fiscal expenditure on the income gap could be strengthened by 11.5%. The expenditure share of the other categories would not significantly change the effect.

Columns (2) and (3) indicate the potentially distinct role of fiscal expenditure structure across regions. Column (2) shows that among provinces with poverty-stricken counties, the shares of agricultural support and rural construction expenses strengthen the impact of fiscal expenditure on the urban–rural income ratio. Specifically, with a 1 percentage point increase in the share, the impact is strengthened by 8.1% for agricultural support expenses and 8.3% for rural construction expenses. Column (3) shows that the results among the WDP provinces are generally similar to those in Column (1), as only the share of agricultural support expenses matters for the impact of fiscal expenditure on the income gap. However, with a 1 percentage point increase in this share, the impact would only be strengthened by 7.9%, smaller than that found for all provinces considered together. Thus, for the western provinces, the expenditure structure is less important, as each yuan of fiscal support tends to yield a greater impact on the

Table 5-2 Heterogeneities Across Fiscal Expenditure Categories

	(1)	(2)	(3)
ln(expenditure)	-0.0610^{*} (0.0324)	-0.117^{***} (0.0375)	-0.145^{**} (0.0704)
×Share of agricultural support expenses	-0.00701^{*} (0.00387)	-0.00952^{**} (0.00412)	-0.0114^{*} (0.00597)
×Share of rural construction expenses	-0.00597 (0.00391)	-0.00975^{**} (0.00420)	-0.00247 (0.00707)
×Share of financial support expenses	-0.295 (0.234)	-0.219 (0.263)	-0.625 (0.497)
Region	Nationwide	Provinces with poverty counties	Western development provinces

Note: Standard errors in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10%.

income gap regardless of the expenditure category; the economic development effect brought about by each unit of fiscal expenditure in support of agriculture matters in the undeveloped western region.

5.3.3 Mechanisms of impacts

In line with the literature, we consider three vital mechanisms through which the fiscal expenditure on agriculture affects the urban–rural income gap. First, the fiscal support may benefit farmers' income by improving agricultural production conditions (Li and Qian, 2004; Shen and Zhang, 2007; Lv et al., 2015) and easing capital constraints (Wen and Dong, 2011; Zhao and Zhu, 2015; Ma et al., 2020; Zhang and Zhou, 2021). Second, the fiscal support induces labor reallocation away from agricultural sector by increasing agricultural productivity (Zhu, 2003) and raising rural human capital (Guo, 2005; Chen, 2010; Li et al., 2017). Finally, the fiscal support can also promote economic transformation toward a more integrated rural industry system between agricultural and non-agricultural sectors, providing rural residents with more income sources (Zhao et al., 2017; Li and Ran, 2019). To identify these mechanisms, we consider the following mediation model:

$$\text{Channel Variable}_{it}=C+\alpha\ \ln(\text{expenditure}_{it})+\gamma X_{it}+\mu_i+u_t \quad (5.3)$$

$$\text{Gap}_{it}=C+\alpha\ \ln(\text{expenditure}_{it})+\beta\ \text{Channel Variable}_{it}+\gamma X_{it}+\mu_i+u_{it} \quad (5.4)$$

In Equations (5.3) and (5.4), Channel Variable_{it} represents the respective mediator that corresponds to the three mechanisms outlined above. We construct the urban–rural difference in income growth rates to identify whether the fiscal expenditure on agriculture narrows the urban–rural income gap by increasing farmers' income. We measure the employment share of the non-agricultural sector to identify whether the fiscal expenditure reduces the income gap by facilitating rural labor reallocation. The income growth and non-agricultural employment share are calculated using data from the statistical yearbooks of provinces. Finally, we investigate the mechanism of rural industrial integration by calculating the growth rate of food system GDP, measured using the logarithm of food system GDP. The food system incorporates agriculture and related sectors such as food manufacturing, fertilizer, and agricultural machinery production. We follow the definition of food system GDP proposed by Zhang et al. (2021) and calculate the food system GDP of China's provinces using the input–output tables for 1997,2002,2007,2012, and 2017. The third mechanism is examined using sample data from these five years. Using these mediators, the existence of each mechanism is confirmed if the fiscal

Table 5-3 Channel Analyses of Fiscal Expenditure for Agriculture on Urban–rural Income Gap

	Difference of growth rate of urban–rural income	Gap	Share of non-agricultural employment	Gap	ln（food system GDP）	Gap
	(1)	(2)	(3)	(4)	(5)	(6)
ln（expenditure）	-0.0184*** (0.00512)	-0.0534* (0.0312)	4.630*** (0.449)	-0.00662 (0.0333)	0.0972** (0.0467)	-0.0459 (0.0620)
Difference of growth rate of urban–rural income		0.757*** (0.244)				
Share of non-agricultural employment				-0.0105*** (0.00273)		
ln（food system GDP）						-0.733*** (0.132)

Note: Standard errors in parentheses. ***, **, * denote statistical significance at 1%, 5% and 10%.

expenditure significantly influences the mediator in Equation (5.3) whereas its impact on the income gap is tempered after controlling for the mediator in Equation (5.4) compared to the benchmark model.

Table 5-3 reports the estimation results for Equations (5.3) and (5.4). Column (1) suggests that the fiscal expenditure on agriculture significantly reduces the urban–rural difference in income growth rates, whereas Column (2) finds a 15% reduction in the influence of fiscal expenditure on the urban–rural income ratio from the benchmark case in Table 5-1 when controlling for income growth differences. Such results confirm the mediating role of the first mechanism. Columns (3) and (5) show that the fiscal expenditure on agriculture significantly promotes both the employment share of the non-agricultural sector and the growth of the food system GDP. Meanwhile, Columns (4) and (6) reveal that the significant impacts of the fiscal expenditure on the urban–rural income ratio disappear after these mediators are controlled for. Consequently, these results confirm the existence of the second and third mechanisms.

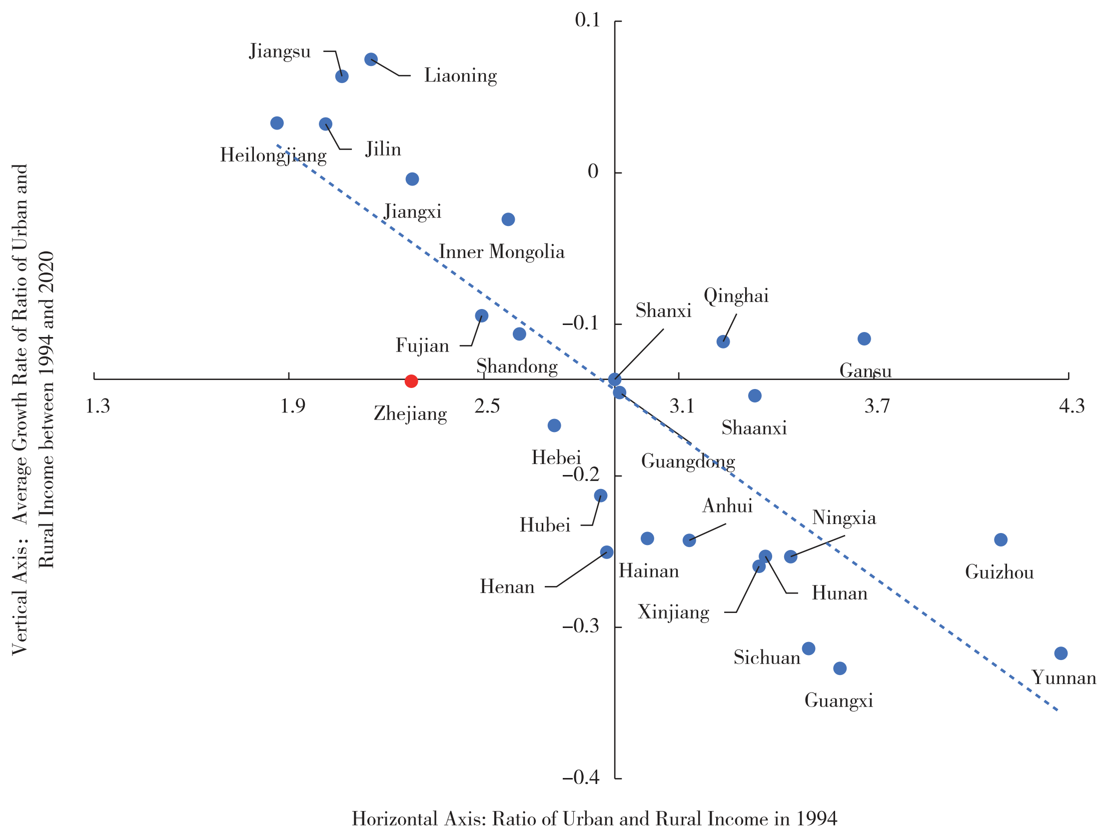
5.4 Innovations and achievements of Zhejiang's fiscal system for agriculture support

Since the reform and opening-up, Zhejiang has been one of the provinces with the most modernized agriculture and active rural economy and the best living conditions for rural residents. Since 2005, Zhejiang has ranked first among all provinces in terms of rural per capita disposable income for 15 consecutive years. Given these achievements, Zhejiang undertook the task of building the "window" for fully demonstrating the superiority of the socialist system in 2020 and establishing the demonstration zone of common prosperity in 2021. As of the end of 2021, the urban–rural income ratio of Zhejiang has dropped to 1.94, far lower than the national average. Highways and the public transit system cover all its counties and villages. Among the rural households of Zhejiang, 86% can access natural gas. The rates of access are 97% for indoor water-flushing toilets, 33% for private cars, 95% for reliable drinking water, 90% for public kindergartens, and approximately 100% for home-based care centers for older adults in towns (Han, 2022).

Zhejiang's narrow urban–rural income gap relies on its relatively small initial gap and fast convergence rate. Figure 5-7 depicts the average annual growth rate of the urban–rural income gap from 1994 to 2020 versus the initial gap in 1994 among all provinces and shows that Zhejiang lies to the lower left of the fitted line. Zhejiang enjoyed a relatively small urban–rural income gap in 1994 because of its leading role in economic reforms and a vigorous private sector that generated non-agricultural income for rural residents. In fact, TVEs accounted for 70% of the total output of Zhejiang's industrial sector in 1994. The share of rural residents' agricultural operating income was only 32.58%, less than half of the national average in the same period. Zhejiang experienced fast convergence of the urban–rural income gap for two primary reasons. First, it had a strong county economy owing to two rounds of county empowerment reforms since 2002. During the past two decades, Zhejiang has always ranked among the top three in terms of number in China's 100 strongest counties. In 2020, the public budget revenue of 30 counties in Zhejiang exceeded three billion yuan. A strong county economy provides non-agricultural income sources to rural residents. In 2020, only 7.5% of the rural income in Zhejiang comprised agricultural operating income. This share was less than one-third of the national average. Second, Zhejiang's agricultural productivity has significantly improved as well, providing a strong boost to the farm income of rural residents. From 1994 to 2020, Zhejiang's per capita value added in the primary industry grew by approximately 28 times, much faster than the national average growth of 17 times. This strong county economy and agricultural productivity growth is a result of Zhejiang's innovative fiscal agricultural policies.

During the past two decades, Zhejiang's fiscal system inventions in agriculture have mainly developed in two stages. The first stage ranged from 2002, with the proposed "Coordinated Urban–Rural Development" strategy, to 2011, before the 18th National Congress of the CPC. As mentioned in Table 5-4, Zhejiang has primarily implemented three innovative strategies during this stage—the Cooperation between Mountainous and Coastal Areas, the Green Rural Revival Program, and the Rural Cooperation System Reform. Among them, the Cooperation between Mountainous and Coastal Areas was initiated in April 2002. It aimed for coordinated

Figure 5-7 Average Annual Growth Rate of the Urban–rural Income Gap Versus the Initial Value, 1994–2020[5]



Source: Statistical Yearbook of provinces (1994-2020).

development within the province by transferring industries and human resources from more developed coastal areas to less-developed mountainous areas. Consequently, Zhejiang established a specific fund to foster industrial parks for inter-regional cooperation. The number of specific subsidies allocated to each park was determined by a comprehensive evaluation of its performance in the previous year. In addition to providing fiscal compensation, the cooperation program also induced private capital inflows by stimulating the market vitality of mountainous areas.

The Green Rural Revival Program was designed to cater to the prospect of "green Zhejiang," proposed by Xi Jinping in 2003 as the CPC Secretary of Zhejiang. The program aimed for beautiful countryside construction by focusing on rural living conditions and agricultural non-point pollution. It was promoted in four stages: demonstration and guidance, remediation, and promotion, deepening and upgrading, and transformation and upgrading. During this process, Zhejiang used the related fiscal funds, including the funds for beautiful countryside construction, "one project, one discussion" reward, and comprehensive rural reforms.

The Rural Cooperation System Reform was initiated in 2006. The reform aimed to build a trinity system by integrating three main categories of farmer cooperatives: production, supply and marketing, and credit. Through the reform, China's double-layered agricultural operation system (i.e., rural collective economic organizations and individual farmers) was consolidated, new agricultural entities were promoted, and the capacities of the cooperative system and socialized agricultural services were enhanced. To encourage the reform, Zhejiang included expenses on the construction of agricultural product circulation networks and farm produce markets under the fiscal expenditure on agriculture. Meanwhile, considerable tax alleviations were provided to the rural cooperatives.

[5] The data of four province-level municipalities, Tibet, Hong Kong, Macao and Taiwan of China are not included.

Table 5-4 Zhejiang's Major Innovative Measures in the Fiscal System of Agriculture Support

Innovation Measures	Implementation Period	Policy Goals	Expenditure
Cooperation between Mountainous and Coastal Areas	2002-Now	Based on the principle of government promotion, market operation, mutual benefit and common development. Strengthen project cooperation between developed coastal areas and underdeveloped areas such as mountainous areas and islands in Southwest Zhejiang in industrial development, new rural construction, labor training, employment, and social development.	About 10 million yuan per year before 2013 and 200 million yuan per year for Coast-mountains Cooperation industrial park construction special subsides.
Green Rural Revival Program	2003-Now	Renovate about 10000 administrative villages and build about 1000 administrative villages into comprehensive well-off demonstration villages.	From 2003 to 2007, the province's total fiscal investment was more than 60 billion yuan.
Trinity Reform	2006-Now	Build a Trinity farmers' cooperative economic organization system of production, supply and marketing and credit. Build an effective operating system and mechanism. Create a service complex for rural household operation and commodity circulation, an integrated agricultural operation and service industry community, and a supply intermediary for agricultural public services and policy implementation.	The completed wholesale market for agricultural products reached 101.6 billion yuan, accounting for nearly half of the total in the province. A farmers' Cooperation Fund was established, with a total scale of 1.89 billion yuan.
Low-income Doubling Plan	2013-2017	By 2017, double the per capita net income of low-income rural residents in 29 counties comparing to 2012. Per capita net income of low-income rural residents reaching more than 10000 yuan (current price). More than 70% of low-income rural residents' per capita net income income will exceed 8000 yuan (except subsistence allowance households). The relative gap between the per capita net income of low-income rural residents and provincial rural residents is narrowing.	From 2015 to 2019, a total of 3.869 billion yuan of provincial fiscal special poverty alleviation funds were arranged. Zhejiang got 1.055 billion yuan of central fiscal poverty alleviation funds.
Five Strategies of Water Management	2017-Now	Sewage treatment, flood prevention, drainage, water supply and water saving. In rural, according to the scale and environment of rural domestic sewage treatment facilities, take anti-leakage, anti-blockage, anti-damage and anti-failure as the main task, establish systems such as data monitoring, patrol maintenance and equipment replacement, so as to realize the long-term stable operation of rural domestic sewage treatment facilities.	Zhejiang raised more than 60 billion yuan in fiscal funds at all levels.
Action of Eliminating Economically Weak Villages	2017-2020	Completely eliminate weak villages with an annual income of less than 100000 yuan in the collective economy.	The total provincial fiscal investment is about 350 million yuan.

Box 5.1 The new village for gathered living project in Tongxiang

The new village for gathered living project in Tongxiang, a county-level city in Zhejiang, has made great strides, backed by the Green Rural Revival Program, and has significantly narrowed the urban¬–rural gap in living environment. For example, in 2005, Huifeng village in Tudian town was a weak and poor village with debt of over 800,000 yuan. In 2008, Huifeng village began to build a new village to promote the construction of beautiful villages. The village successfully realized the circulation of 6,000 Chinese acres of land. Moreover, it raised funds through land consolidation, homestead reclamation, rectification, demolition, and other projects, which revitalized the land and provided a foundation for subsequent development. The new village for gathered living project has greatly improved the living environment, and Huifeng village plans to facilitate the move of at least two-thirds of the residents to the new village by 2035. For the remaining one-third, as their houses have been renovated or constructed in recent years, they will not move to the new village for the time being. Huifeng village is expected to complete the construction of phase V of the project and acquire 220 households in the next five years. In addition to the new village for gathered living project, Huifeng village has also improved the living environment by upgrading infrastructural facilities and renovating and constructing sewage systems. It is expected to conduct reconstruction and repair of all roads in the village before the end of 2025. At least six to seven rural roads will be reconstructed every year. The main roads will be hardened, lightened, and greened. Huifeng village will also make efforts to construct gas and other pipeline services, communication facilities, and parking space. A total of eight million yuan will be invested to improve living supporting facilities. In the next five years, Huifeng village also plans to invest two million yuan in completing the dredging of 21.7 kilometers of river channels in the village to improve the river water quality and control droughts and floods. Moreover, the village has implemented the system of long-term river cleaning and assigned responsibility to specific people. The improvement of the living environment has laid a foundation for developing rural tourism, promoting inter-sectoral integration, and increasing rural residents' income. In the recent years, Huifeng village has developed tourism through transferred land, setting up the tourist area of Kangxin Cultural Park. Fengyu, an ecotourism development company managed by the village, is the main platform for tourism development. The company contributes toward building a rural tourism brand by cooperating with travel agencies.

In 2019, Huifeng village was rated as a 3A scenic village and Kangxin Cultural Park as a national 3A scenic spot. Since 2019, 1.25 million tourists have visited Kangxin Cultural Park. In 2020, the per capita income of rural residents in Huifeng village reached 41,845 yuan, and the collective disposable capital reached 3.27 million yuan. Kangxin Cultural Park also brought about 15 million yuan of indirect income for the surrounding villagers through farmhouses, home stays, and the sale of agricultural products. In addition, Huifeng village has also introduced the Wanhe Agricultural Wisdom Valley project, with a phase I investment of 100 million yuan. The project aims to build Zhejiang's first smart agriculture demonstration area by integrating technological research, popular science exhibitions, thriving agriculture, and entrepreneurship incubation. The new village for gathered living project has thus directly contributed to narrowing the living environment gap between urban and rural areas. The project also plays a key role in developing rural tourism and the collective economy, improving agricultural efficiency, increasing villagers' income, and narrowing the urban–rural income gap.

Since the CPC's 18th National Congress, Zhejiang has continued to innovate in the fiscal system of agriculture support. The Income Doubling Project for Low-Income Rural Households (hereafter, Income Doubling Project) and Five Strategies of Water Management are the primary measures that were adopted during this stage. Initiated in 2013, the Income Doubling Project aimed to increase rural residents' income through paired assistance and social forces, especially based on special actions to support less-developed regions and the Cooperation between Mountainous and Coastal Areas. During this process, Zhejiang created a special integrated fund by combining fiscal expenses and credit support and leveraging social assistance for poverty alleviation. Moreover, it also promoted microcredit loans and mutual aid networks for poverty alleviation to provide employment assistance to rural residents. Such strategies have effectively facilitated the construction of long-term institutions with targeted assistance such as relocation for poverty alleviation, infrastructure construction, and investment in economic development projects.

The Five Strategies of Water Management project is being implemented since 2014 and includes sewage treatment, flood prevention, drainage, water supply, and water saving for beautiful countryside construction. For the project, Zhejiang has established a preferential fiscal system with overall fiscal policy planning, budget planning, and project management. Zhejiang has also actively leveraged social capital by project funds, which effectively amplifies the effects of fiscal funds.

In addition to the Income Doubling Project and Five Strategies of Water Management, Zhejiang has also proposed the Action of Eliminating Economically Weak Villages. This action aimed to stimulate the internal forces of economic growth by energizing the stock of rural land and collectively-owned rural assets in villages with less than 100,000 yuan of collective income. Simultaneously, by executing the upgraded Cooperation between Mountainous and Coastal Areas project and innovative cooperation approaches such as creating an "enclave economy" for less-developed regions in coastal industrial parks, Zhejiang effectively injected talents, technology, capital, and other resources into mountainous areas. The special fiscal fund has played a demonstrative and driving role in leading project construction and social capital investment throughout this process (Wang et al., 2020).

Box 5.2 The "Enclave Economy" of Kaihua

As one of the 26 mountainous counties in Zhejiang, Kaihua County has always been the key recipient of the fiscal expenditure on agriculture. Since 2002, Zhejiang has launched the Cooperation between Mountainous and Coastal Areas to support the sharing of resources across regions. In the process, the government, enterprises, and social capital have been encouraged to promote the economic and social development of the 26 counties. The Enclave Economy for Coordinated Growth is an important method for Cooperation between Mountainous and Coastal Areas. In 2019, Kaihua County and Tongxiang City reached an agreement on the Cooperation between Mountainous and Coastal Areas enclave industrial park projects that increased rural residents' income and collective income in Kaihua by offering land conversion quotas for Tongxiang. The industrial park entrusted by Kaihua is operated by Tongxiang, and the operating income will be used to eliminate 30 weak villages in Kaihua. The project is being implemented in two phases with a total investment of 30 million yuan. It has adopted the Enclave Economy for Coordinated Growth mode, characterized by overall county planning, joint-stock operation, and minimum dividend.

Thirty villages with a weak collective economy in Kaihua are being guided to share in the land indicators and funds. Backed by new land policies such as land indicator adjustment across cities, land indicators of weak villages are transformed into collective income. The vitality of village development is stimulated in the process of space replacement. Presently, Tongxiang has provided the Puyuan Group project, a completed city–village collective economic growth project, as a cooperation platform. This platform provides Kaihua with profits of approximately 2.4 million yuan annually, increasing the collective income of 80,000 yuan for each weak village. As one of the 30 weak villages in Kaihua, Hualian village won the first income of 50,000 yuan from the Enclave Economy for Coordinated Growth project at the end of 2019. Then, the fund was further used to develop the Qingshui fish breeding industry. The planned phase I project of the Junlong Qingshui fish industrial park established a 15 Chinese-acre Qingshui fish farm, water diversion, roads, and other supporting facilities. It is expected to achieve an annual output value of 600,000 yuan and increase the village's collective income by 200,000 yuan upon completion. In addition, the phase II project of the Qingshui fish farm has also been preliminarily planned. The tourism projects such as road beautification, farmhouse improvement, Qingshui fish processing, and fishing will be implemented sequentially.

Qingshui fish is a specialty of Kaihua. It was approved as a national agricultural geographical indication product by the Ministry of Agriculture and Rural Affairs in 2020. Encouraged by the Enclave Economy for Coordinated Growth, the local government has also invested considerable funds to support the development of the Qingshui fish industry in the past two years. In addition to Hualian village, Youhao village is also a typical case. Through Kaihua's investment promotion, Qinyang Agricultural Development Co., Ltd. settled in Youhao village, invested 5.8 million yuan, and transferred 40 Chinese acres of collective land in the village to build a Qinghsui fish breeding base. The company also improved the village infrastructure and the living and ecological environments. In 2018, the Investment Promotion Bureau of Kaihua County issued the implementation opinions on accelerating the development of the Kaihua Qingshui fish industry. The opinions proposed the development goals of the Qingshui fish industry from 2018 to 2022. By 2022, the breeding area of Qingshui fish will reach 3,000 Chinese acres, with 12,000 breeding pits and ponds and 10,000 employees. The breeding industry will bring an additional 10,000 yuan of income for each household. As of July 2021, phase I of the Youhao village Qingshui fish breeding base project has led to the construction of 2 thousand-square-meter fishponds and 72 thirty-square-meter high-quality fishponds. Additionally, nearly 3,000 kg of fry have been placed, and the construction of channels, drainage ditches, roads, and other infrastructure has been completed.

The Enclave Economy for Coordinated Growth project supported by the local government has effectively promoted the growth of the collective village economy, increased rural residents' income, and played a key role in narrowing the urban–rural income gap.

According to available statistics, Zhejiang has devoted over 245 billion yuan since 2015 into the Cooperation between Mountainous and Coastal Areas, Income Doubling Project, Action of Eliminating Economically Weak Villages, and other innovations in its fiscal system of agriculture support. Among them, approximately 97% have been in terms of fiscal transfers to the 26 mountainous counties. The amount of fiscal support for constructing industrial parks under Cooperation between Mountainous and Coastal Areas is approximately 200 million yuan per year. Each year, Zhejiang also allocates 70 million yuan to the Action of Eliminating Economically Weak Villages and more than doubles the central government funds to develop the "enclave economy." Collectively considering the Green Rural Revival Program, Five Strategies of Water Management, and other related projects, Zhejiang has cumulatively invested over 183 billion yuan of provincial fiscal funds to improve the rural ecological environment. Approximately 60 billion yuan has been invested in beautiful countryside construction, which further leveraged 77 billion yuan of social investment. Another 60 billion yuan has been allocated to the Five Strategies of Water Management, with 4.5 billion yuan of special investment to treat rural domestic sewage in 2017.

Compared to other provinces, Zhejiang's innovations in the fiscal system of agriculture support exhibit three noteworthy features. First, Zhejiang has provided strong fiscal support to agriculture by mobilizing abundant local funds beyond central government transfers. From 2012 to 2020, the average annual growth rate of agricultural fiscal expenses reached 5.47% in Zhejiang, higher than that of its GDP in the same period. Relative to the other provinces, Zhejiang gets fewer fiscal transfers for agriculture from the central government because of its developed agricultural and rural sectors. However, Zhejiang has ensured full and stable investment in agriculture by devoting a large amount of its provincial fiscal funds. For instance, in terms of the special fund for poverty alleviation, Zhejiang's provincial investment was 3.26 times that of the central government's fiscal transfers over 2012–2020. This ratio of provincial investment to fiscal transfers is much higher than that in provinces with a heavy reliance on fiscal transfers, such as Guizhou and Yunnan, where the ratio has remained below 1. It is also 1.6 to 4 times higher than the ratio of its neighboring provinces like Jiangsu and Fujian.

Second, Zhejiang has attached immense importance to sustainable development in its fiscal system of agriculture support by highlighting inter-regional coordination and improvements in the rural living environment. Zhejiang launched the Green Rural Revival Program in 2003, a decade before the nationwide implementation of the Beautiful Countryside Construction Program. In 2019, Zhejiang's expenditure on Cooperation between Mountainous and Coastal Areas, Action of Eliminating Economically Weak Villages, and the Green Rural Revival Program accounted for 9.21%, 3.06%, and 7.18% of the total expenditure on agriculture, forestry, and water affairs, respectively.

Finally, Zhejiang has actively leveraged social capital to reinforce the impact of fiscal support on agriculture. In 2016, Zhejiang established a system of rural credit guarantees backed by a fiscal investment of 900 million yuan. In 2020, Zhejiang injected 640 million yuan of fiscal capital as guaranteed funds into the system, resulting in a balance that exceeded 3.29 billion yuan, which was 5.14 times the fiscal expenditure. This system has effectively alleviated the financial constraints on agricultural and rural development.

5.5 Conclusion and recommendation

Since the reform and opening-up, sustained growth and structural improvements have been witnessed in China's fiscal expenditure on agriculture. After the CPC's 18th National Congress, the fiscal system was further enriched, and funds were utilized more intensively, which yielded strong support for the Rural Revitalization Strategy. Our empirical findings have revealed that fiscal expenditure on agriculture has effectively narrowed the urban–rural income gap, and the effect has been greater in the less-developed areas and during the last decade. Among the fiscal expenditures, agricultural production expenses and rural poverty alleviation exhibit larger impacts than other spending categories. There are primarily three mechanisms whereby fiscal expenditure narrows the income gap: stimulus to farmer income, accelerated rural labor reallocation to non-agricultural sectors, and closer integration between agriculture and other industries. As a province leading the achievements in narrowing the urban–rural income gap, Zhejiang has adopted a series of innovations such as the Cooperation between Mountainous and Coastal Areas and the Green Rural Revival Program in its fiscal system of agricultural support. Compared to other provinces, Zhejiang's fiscal system has exhibited three key features, including more local funds in addition to the central government's expenditure, greater expenditure directed toward sustainable growth, and effective leverage of social capital.

Presently, reducing the urban–rural income gap is still the top priority for achieving the goal of common prosperity. By analyzing China and Zhejiang's fiscal systems of agriculture support, this study proposes the following policy recommendations for China to further promote the income equalization of urban and rural residents in the future.

First, China should further improve the expenditure structure and spatial distribution of the central government's fiscal expenditure on agriculture and increase the accuracy and efficiency of fiscal policies. This study shows that the effect on the urban–rural income gap of fiscal expenditure on agriculture differs based on the structure and allocation of expenses. Therefore, less-developed areas and important agricultural production areas in central and western China should receive attention during the allocation of the central government's fiscal expenditure on agriculture. Meanwhile, the central government's expenses should preferentially be invested in key domains such as agricultural production, agricultural and rural construction, and poverty alleviation. In addition, a redistribution system with reward and punishment must be explored to establish a supervisory mechanism for effective fiscal transfers based on the efficiency of fund use.

Second, China should encourage local governments to tailor the fiscal system of agriculture support to fit the local context by fully exploring the dimensions of agriculture in the rural areas. Zhejiang's experience shows that expenditure on sustainable rural development and diversified sources of investment funds could significantly improve the welfare of rural residents. Therefore, developed areas should invest more in sustainable rural development and enhance coordinated economic and ecological growth between urban and rural areas. However, Zhejiang's success depends on its developed agricultural sector and a more advanced marketization process. Thus, for less-developed and major grain-producing areas, fiscal policies should strengthen the linkages between the Rural Revitalization Strategy and food security and poverty alleviation. It is also important to innovate the funding pattern for agricultural support by establishing diversified sources leveraged by the fiscal system.

Finally, the fiscal system for agriculture should coordinate with other agricultural and rural development policies to jointly promote integrated urban–rural development. The empirical results have shown that fiscal expenditure on agriculture can narrow the urban–rural income gap by promoting the reallocation of rural labor to non-agricultural industries and enhancing the integration between agriculture and non-agricultural industries. Therefore, local governments should further strengthen the county economy to promote industrial relocation from coastal and urban areas, thereby accelerating rural labor reallocation. A fiscal transfer institution to address the citizenship issues of rural migrants should also be created to support rural migrants in cities. Moreover, China must completely eliminate barriers to urban–rural factor flows to induce human and physical capital, information, and data flows to rural areas. The rural industry layout should be improved upon by completing rural industrial chains and enhancing the quality of the food processing industry, which serves as a key strategy for rural industrial integration. Furthermore, it is necessary to continuously ameliorate the environment for innovation and entrepreneurship in rural areas, promote the development of new industries with new formats by increasing investment in technologies like digitalization, and promote the integrated development of urban and rural industries.

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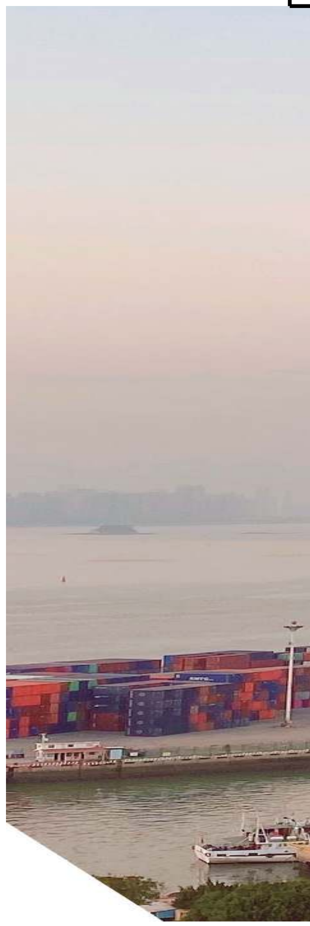
Appendix Table 5A Descriptive Statistics for Main Variable

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Gap	667	2.730	0.506	1.662	4.211
ln(expenditure)	667	4.635	1.473	1.245	7.178
Agricultural supports/ total fiscal expenditure,%	667	12.63	14.98	0.192	81
ln(per capita GDP)	667	8.290	0.836	6.332	10.22
$\ln^2$ (per capita GDP)	667	69.41	13.87	40.09	104.4
Employment share of SOEs	667	11.71	6.387	3.880	42.59
Total imports and exports/GDP, %	667	22.18	26.49	1.796	180.3
Total fiscal expenditure/GDP, %	667	19.15	10.68	4.917	75.83
Share of agricultural support expenditure	187	0.545	0.234	0	0.998
Share of rural construction expenditure	187	0.364	0.218	0.00189	1
Share of financial support expenditure	187	0.00207	0.00271	0	0.00611
Difference of growth rate of urban-rural income	642	-0.00652	0.0394	-0.0895	0.0734
Share of non-agricultural employment	666	53.84	13.02	17.85	92.18
ln (food system GDP)	129	16.37	1.141	13.05	18.39

Chapter 6



Reforming China's Domestic Agricultural Support under the International Trade Framework

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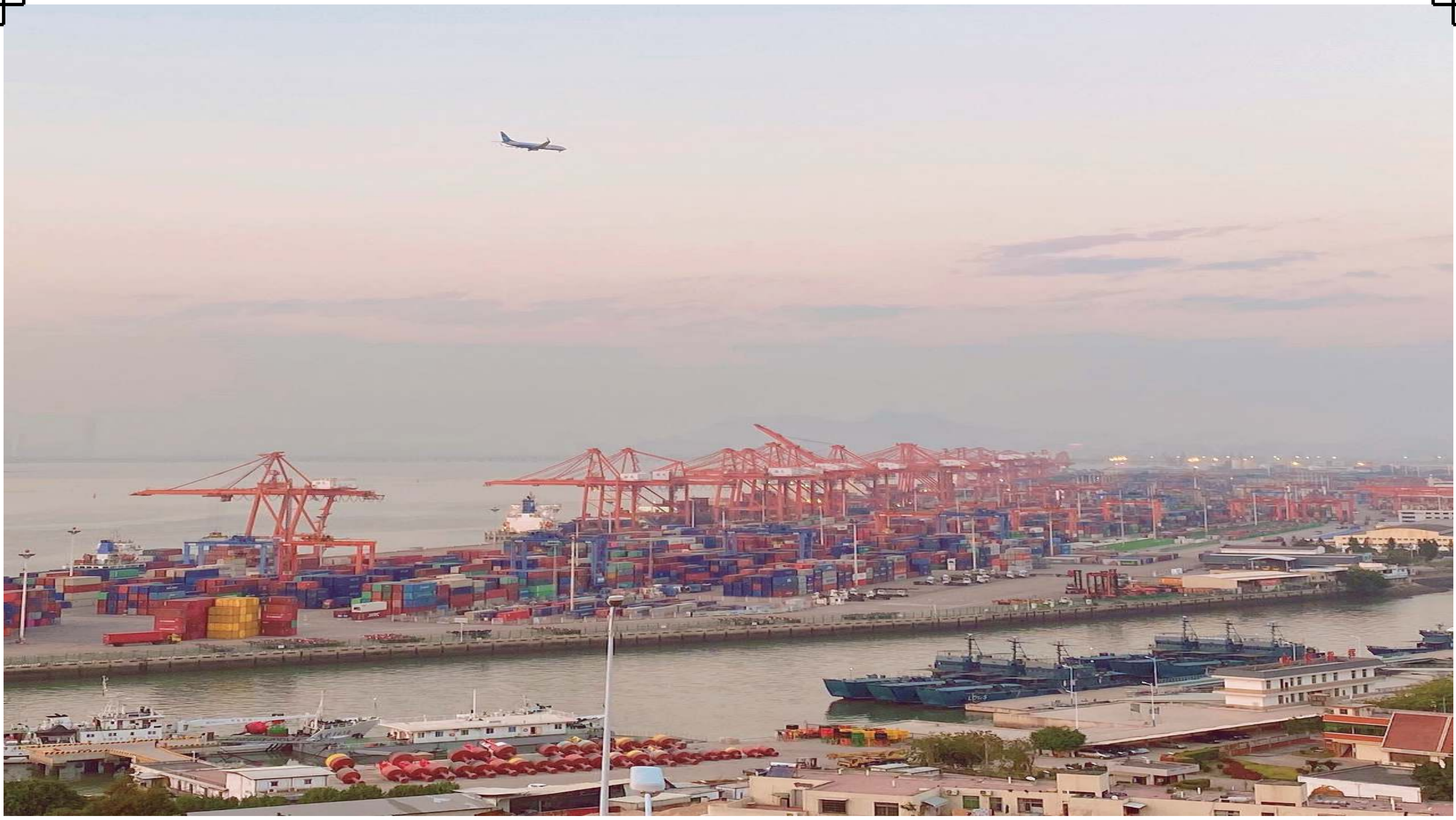
Key Findings

● As China becomes increasingly connected to international markets, it's domestic agricultural support and protection policies face new challenges. On the one hand, China must effectively bridge competitiveness gaps and reduce the influx of "non-essential" agricultural imports; on the other hand, it must address escalating pressure from international trade disputes and the constraints of international rules.

● Since 2016, China has been exploring the construction of a new agricultural support and protection policy system, by gradually reducing the minimum purchase price for grains and phasing out the minimum price policies – which are considered to have "amber box" attributes – and exploring a policy-oriented agricultural insurance system with "green box" attributes.

● The practical exploration of China's agricultural support policies that reduce amber box measures and increase green box measures presents new challenges. This is highlighted by the fact that the shift of minimum purchase prices for rice and wheat from market-supported to a price floor does not necessarily guarantee effective returns on grain cultivation. At the same time, policy-oriented agricultural insurance, depending on the institutional design approach, is not always a natural "green box" measure; operation of income insurance is more likely than full-cost insurance to be regarded as a "green box" measure.

● The simulation results of optimization schemes to adapt China's domestic agricultural support policies to the constraints of trade rules show that the economic welfare of grain farmers will be largely unaffected if the minimum purchase price for rice and wheat is lowered to the cost of production and is accompanied by the implementation of full-cost insurance, while the efficiency of fiscal spending will increase significantly. This will produce no significant changes in domestic grain production and import volume, assuming domestic grain consumption will remain relatively stable.



Policy recommendations

● Promotion of agricultural support policies that reduce "amber box" measures and increase "green box" ones should be continued, and the grain minimum purchase price should be gradually reduced to the cost of growing grain to return the minimum purchase price policy to its function of price floor At the same time, full-cost insurance for rice and wheat should be implemented as a complementary policy and its design optimized as a policy-oriented agricultural insurance subsidy that can be treated as a "green box" measure.

● China needs to adapt its domestic agricultural support policies to the constraints of trade rules and reorient its agricultural support policies and national food security objectives in line with its domestic development needs. In the process of shifting from an emphasis on immediate high food production and self-sufficiency to the pursuit of sustainable agricultural development and long-term food security, efforts must be made to build a competitive domestic food production and supply system.

● While building on existing system of international rules system and domestic realities, China needs to participate actively in the negotiation and formulation of international rules and to promote WTO reform and the reshaping of international rules. The inequities between WTO rules for developed and developing countries regarding domestic agricultural support should be rectified in subsequent negotiations. At the same time, China should play a role in issues such as public reserves for food security and agricultural trade to help create a stable and sound new international order.

6.1 Introduction

Ensuring high grain production and a high self-sufficiency rate has long been the primary objective of China's agricultural policy, and the focus of its regulatory objectives and domestic agricultural support policies. The grain price support policy has been among the important and effective policy tools in China's agricultural policy system over the past decade. However, as the integration of domestic and international markets has deepened in recent years, the pressure for "non-essential imports" of grain has intensified. The price support policy has not only posed certain challenges to the effective operation of the domestic grain market, but has also left room for other countries to question, or even sue, China for distorting the international market. In order to adjust and improve its "amber box" measures and expand the application of "green box" measures, China has been implementing a series of initiatives since 2016 to explore the construction of a new grain production support policy system. These pilots include "market-oriented purchase" plus "direct subsidies" under its corn policy; adjusting the minimum purchase price policy for rice and wheat; and transforming and upgrading policy-oriented agricultural insurance. As the world's most populous developing country, the current exploration of China's agricultural support policies, while adapting to international rules, including whether they can safeguard the interests of domestic farmers and balance grain supply and demand and what adjustments and improvements will be needed in the future are important issues that deserve an in-depth analysis.

Based on an in-depth analysis of the current pressure on domestic agricultural support policies, the exploration of policy practices, and potential challenges in reducing "amber box" measures and increasing "green box" measures in China, this chapter adopts a simulation approach to investigate the economic effects of China's possible future agricultural support schemes, with the goal of informing the construction of a new agricultural support and protection policy system that is both appropriate for the national context and in line with international rules.

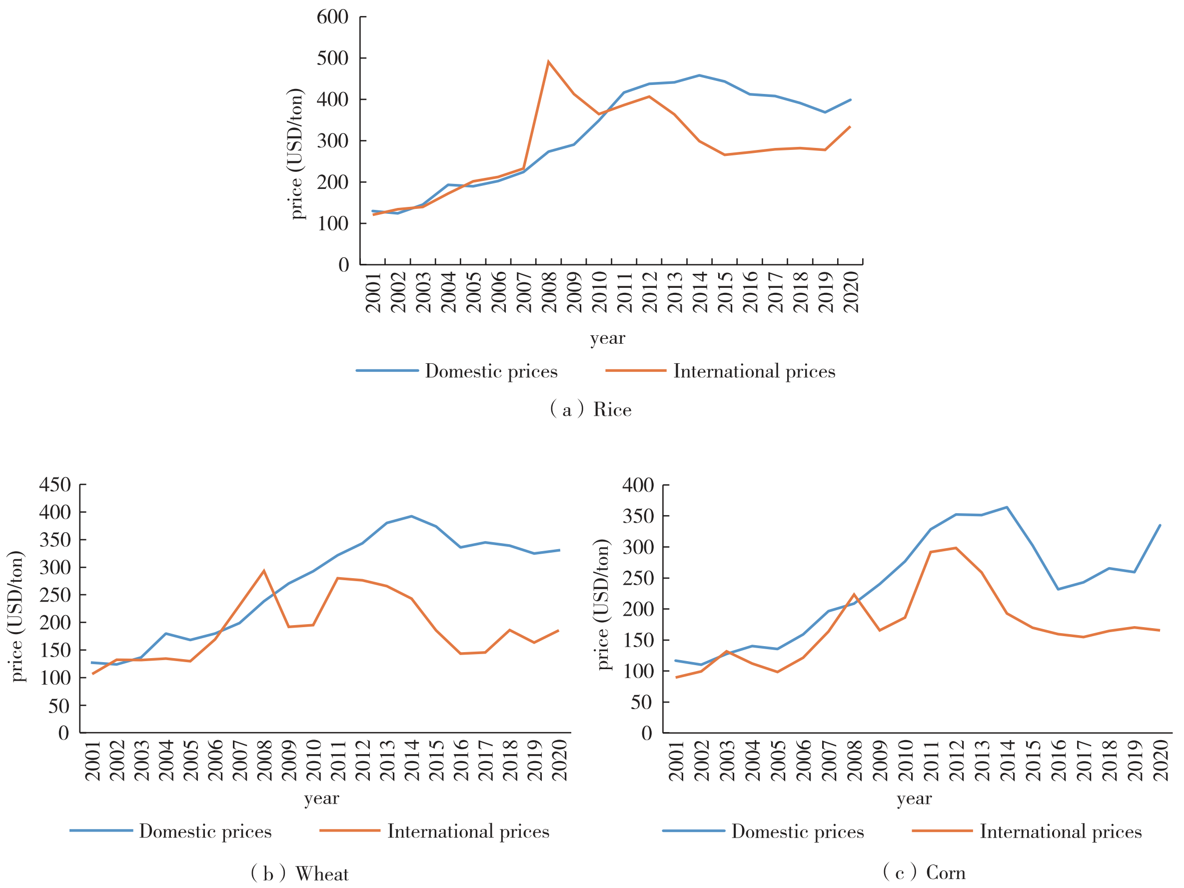
6.2 Current pressure for adjustment of domestic agricultural support policies

Farmers' incomes from grain production in China have risen continually since 2004. Grain price trends have generally remained stable and upward, with the domestic agricultural support system, particularly the minimum purchase price, playing an important role. However, China's domestic agricultural support and protection policies are now facing new challenges as China becomes increasingly connected to international markets. On the one hand, China must effectively bridge basic competitiveness gaps and constrain the influx of "non-essential" agricultural imports; on the other hand, it must deal with escalating pressure from international trade disputes and the constraints of international rules.

6.2.1 Price differential–driven import trade hits domestic grain supply and demand balance

Domestic labor costs for grain cultivation, land costs, and other production factor costs continue to rise in China as a result of industrialization, urbanization, and changes in rural demographics. China's production costs for bulk agricultural products have increasingly approached those of Japan and South Korea, while the cost gap has widened with major exporters such as the United States, Canada, and Australia (Ni et al., 2018). The government's minimum purchase price for major domestic agricultural products has been continuously increased to ensure profitability and maintain farmers' incentive to engage in agricultural production in the face of rising costs. This has driven up equilibrium prices in China's domestic grain market, with domestic and international agricultural prices moving in opposite directions, triggering a serious price inversion between the two. Figure 6-1 shows that the domestic prices of China's three main grains, that is rice, wheat, and corn, have been increasing rapidly since 2009, and are consistently higher than international prices. Domestic prices reached US$398.6 per metric ton for rice, US$330.9 per ton for wheat, and US$334.9 per ton for corn in 2020, putting them 19.1, 78.3 and 102.2 percent, respectively, above international prices.

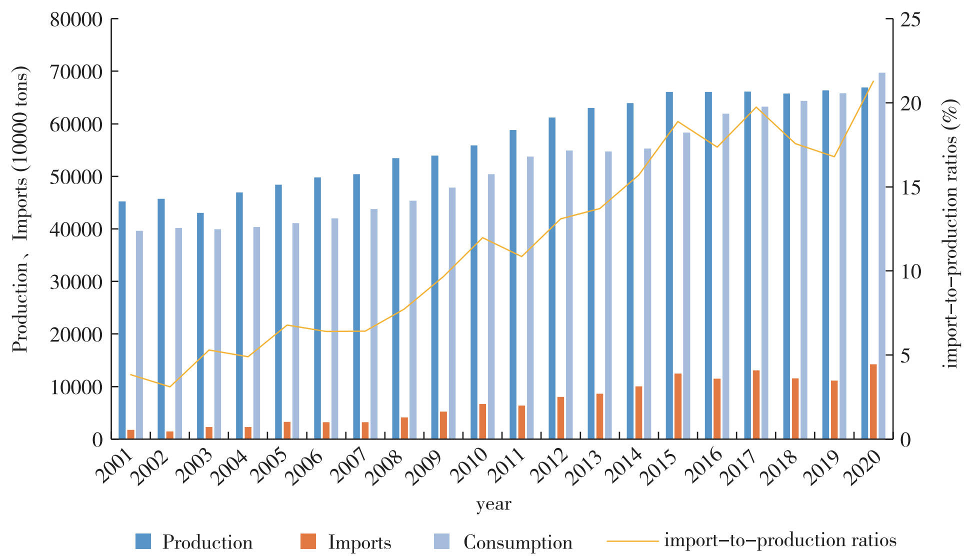
Figure 6-1 Annual Price Trends for Three Main Grains from 2001 to 2020



Source: Domestic price data from the National compilation of cost-benefit information on agricultural products, 2002-2021 (calendar years). International prices are based on data from the International Monetary Fund (IMF) database (https://www.imf.org/en/Research/commodity- prices).

In this context, imports driven by the price differential have become the norm and over-importation has become increasingly problematic; that is, "non-essential" imports of grains—meaning imports exceeding the gap between domestic production and demand—have been increasing dramatically. As shown in Figure 6-2, China's imports of grains, including soybeans, grew rapidly between 2001 and 2020, from 17.38 to 142.55 million tons, an increase of about 7.2 times reflecting an average annual growth rate of 11.7 percent. Over this period, the ratio of imports to domestic production increased from 3.8 to 21.3 percent. More than half of China's food imports from 2012 through 2015 were "non-essential" imports, according to the estimates of the Agricultural Trade Promotion Center of the Ministry of Agriculture and Rural Affairs (2017). The trend of rising labor and land costs in China will be difficult to reverse, and price inversions determined by cost inversions may become the norm in the future. This means that, as China's opening to the outside world deepens, the pressure from price differential-driven grain imports will continue unabated. Increased imports may bring both greater pressure and impact on the regulation of agricultural trade and the development of related domestic industries, and greater impact on farmers' employment and income growth. Thus, China, faced with the impact of growing "non-essential" imports on the domestic grain supply and demand balance, needs to further adjust and optimize its domestic agricultural support policies.

Figure 6-2 Trends in China's Grain Production, Imports, Consumption, and Import-to-production Ratio from 2001 to 2020

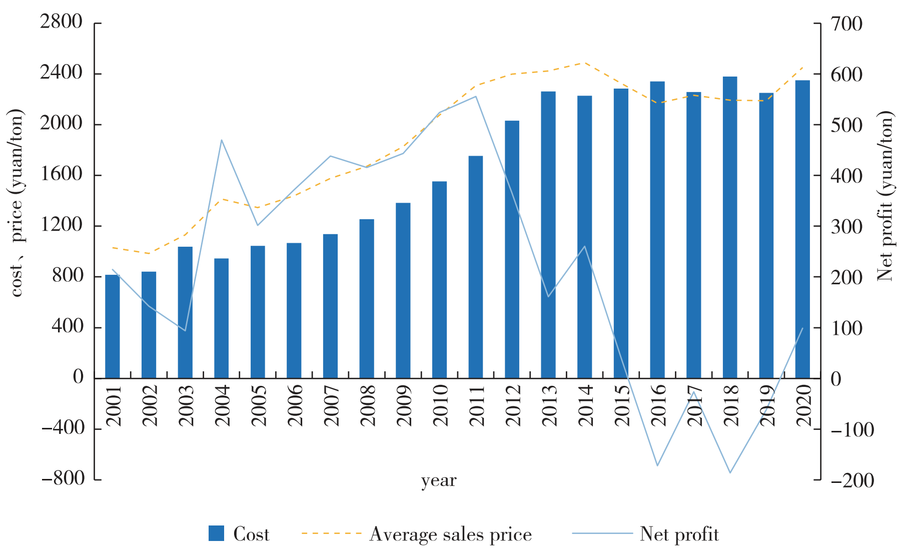


Source: Data on grain production and imports is from China Rural Statistical Yearbook (2002-2021), and grain consumption data are derived from aggregate demand data published in the USDA PSD database.

6.2.2 The import price ceiling reduces the incentive to grow grains while increasing the fiscal burden

The suppressing effect of low-priced global grain imports on domestic prices is becoming increasingly significant as domestic and foreign price inversion gradually becomes the norm; moreover, the ceiling effect of import prices is increasing. This increased competitive pressure on the domestic grain market has lowered returns for farmers and seriously reduced their production incentives. As shown in Figure 6-3, the average growth in sales prices of rice, wheat, and corn in China has gradually slowed since 2011 and began to trend downward in 2014. The net profit per ton of the three grains affected by both falling prices and rising costs fell sharply after peaking in 2011, turned negative from 2016 and decreased further to -62 yuan per ton in

Figure 6-3 Average Cost-benefit of Three Types of Grain in China from 2001 to 2020

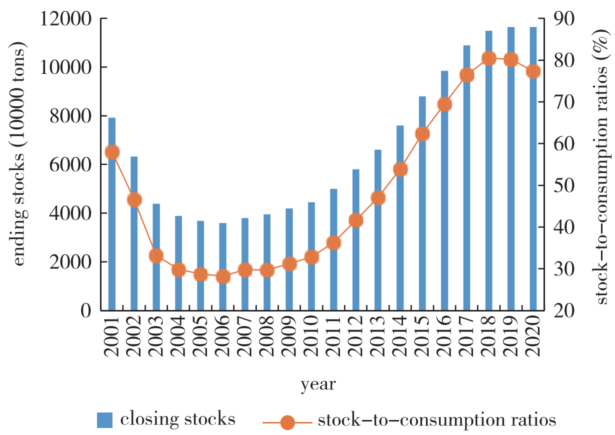


Source: National Compilation of Cost-Benefit Information on Agricultural Products (2002-2021).

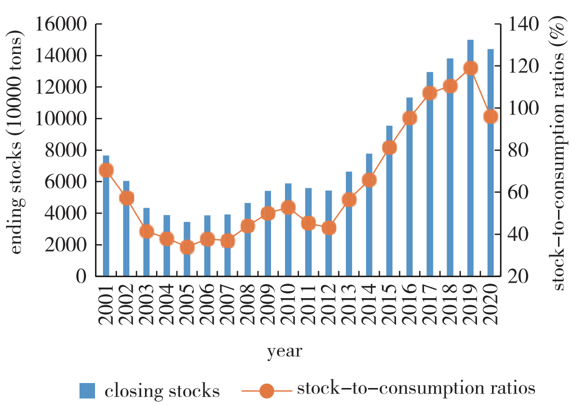
2019, before returning to positive values in 2020.

In addition, the ceiling created by import prices has deprived the policy-oriented market purchase price measures by creating an environment characterized by "low absorption and high dumping, throughput reserves, stabilizing the market and playing a price floor role," as the price differential between domestic and international prices continues to widen. As a result, the minimum purchase price is no longer the market "minimum price" and temporary storage has become "not temporary," in some cases creating a so-called policy market for grains, marked by a set of anomalies such as "storage on the side, import on the side" and "foreign goods into the market, national goods into the warehouse" (Zhu, 2017; Ni et al., 2018). As shown in Figure 6-4, China's stock of rice, wheat, and corn has grown rapidly over the past decade. The stock-to-consumption ratio has long been well above the internationally warning line of 17 to 18 percent, with wheat reaching nearly 120 percent and corn still over 70 percent despite a decline after the removal of the temporary storage policy. These anomalies brought about by grain support and procurement policies have put enormous pressure on the upstream and downstream value chains and the entire distribution chain, as well as imposing a heavy financial burden on the government. The question of how to safeguard farmers' employment and income growth while reducing the government's financial burden in the face of the domestic price impact of large-scale imports of low-priced foreign grain has led to new pressure for the reform of domestic support and subsidies for grain production.

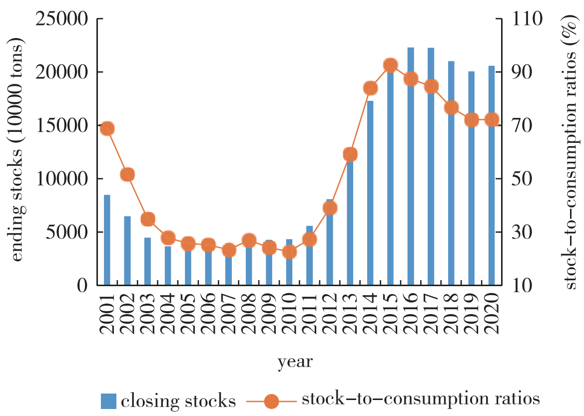
Figure 6-4 Trends in Closing Stocks and Stock-to-consumption Ratios of Three Types of Grain in China from 2001 to 2020



(a) Rice



(b) Wheat



(c) Corn

Source: USDA PSD database's closing stock quantities for grain and total demand data.

6.2.3 Dispute and litigation pressures constrain the options for domestic agricultural support policies

The characteristics of China's resource endowment, namely a large population and a small land area, inherently put China's agricultural production at a competitive disadvantage compared with major exporting countries with abundant land resources, and make it essential to support agricultural production. However, China made significant agriculture commitments at its accession to the WTO, leaving limited room for domestic agricultural support policies. China pledged to reach zero aggregate measures of support after accession to the WTO, capped the "amber box" measures for specific and non-specific farm products at 8.5 percent of the gross agricultural output value,[1] which is below the 10 percent standard for developing-country members, and gave up the right to use the "development box" tailored for developing countries. With the change in national agricultural policy to "give more and take less" after 2004, China's "amber box" expenditure has increased according to the WTO agricultural notification, and the "amber box" support rate for specific products of rice and wheat has approached the de minimis level at 8.5 percent. In September 2016, the United States filed a lawsuit with the WTO Dispute Settlement Body (case DS511) on the grounds that China's domestic support for rice, wheat, and corn producers exceeded its accession commitments. In late February 2019, the WTO panel issued a review report ruling against China.[2]

In addition to domestic subsidy policies, China's other agricultural policies are also facing growing pressure from international rules and challenges in international disputes. First, the frequency of international dispute litigation against China's agriculture sector is increasing every year; second, the range of causes and species involved is expanding; and third, the scale of industries affected by litigation is expanding (Zhu et al., 2021). According to statistics on the WTO website (see Table 6-1), the number of agricultural dispute cases in which China was a respondent from 2016 to 2021 has been as many as six, which significantly more than both the prior frequency of suits against China's agriculture sector and the frequency of suits against other countries' agriculture sectors during the same period. Thought must be given to how to reform and improve the existing domestic food support policy system and to actively designing domestic agricultural policies in alignment with international rules in the future, so that policies can help meet both China's food security needs and the requirements of international rules, and thus avoid unnecessary international disputes and pressure from international public opinion.

[1]According to the WTO Agreement on Agriculture, agricultural domestic support policies are divided into "green box", "amber box," and "blue box". "Green box" measures, which have the least or minimally distorting effects on agricultural production and trade, can be exempted from reduction commitments; "amber box" measures are deemed to have the most distorting effects on agricultural production and trade; and "blue box" measures, which are direct payments under a production limiting program, have limited distorting effects with unlimited supporting level.

[2]WTO panel issued a report in favor of the U.S., noting that China's market price support for wheat and rice from 2012 to 2015 exceeded the de minimis limits for specific agricultural commodities and that China violated its binding commitments under Articles 3.2 and 6.3 of the Agreement on Agriculture.

6.3 Practical exploration and possible challenges to China's agricultural support policies that reduce "amber box" measures and increase "green box" measures

China's agricultural opening has shifted to a new stage of high-level development, with an emphasis on institutional opening as it enters the 14th Five-Year Plan period. Adaptation to international trade rules has become an important issue that must be considered in the transformation of China's agricultural support and protection policies. China has conducted a series of pilots and adjustments to the agricultural support and protection policy system in recent years, with policy guidelines for reducing "amber box" and increasing "green box" measures. However, the country still faces new pressures and challenges from open market competition and international rules, and the adjustment process needs to be further optimized.

6.3.1 Practical exploration of agricultural support policy adjustment in China

China's agricultural support policies were formulated and implemented in response to changes in domestic agricultural and general economic development.

Table 6-1 List of Cases Involving WTO Dispute Settlement Related to China's Agriculture Sector

Case Code	Initiation Year	Initiating Litigation State	Species involved	Cause of action
DS511	2016	USA	Wheat, rice and corn	The U.S. submitted a request to the WTO for consultations on the grounds that China's domestic support for agricultural products such as wheat, rice and corn exceeds China's WTO accession commitments.
DS517	2016	USA	Wheat, rice and corn	The U.S. required China to consult with it regarding the administration of its tariff quotas, alleging that China's administration of tariff quotas for agricultural products such as wheat, rice and corn is inconsistent with its WTO accession commitments and violates the relevant provisions of the GATT 1994.
DS568	2018	Brazil	Sugar	Brazil requested consultations with China on: (i) China's safeguard measures on sugar imports; (ii) China's tariff quota management for sugar; and (iii) China's import licensing system for out-of-quota sugar imports.
DS589	2019	Canada	Oilseeds	Canada requested consultations with China on: (i) measures to suspend imports of oilseeds from two Canadian companies, and (ii) measures to conduct enhanced inspections of all imports of oilseeds from Canada.
DS598	2020	Australia	Barley	Australia has requested consultations with China on certain measures to impose anti-dumping duties and countervailing duties on barley imports from Australia.
DS602	2021	Australia	Wine	Australia has requested consultations with China on anti-dumping and countervailing measures on imports of bottled wine from Australia in containers of 2 liters or less.

Alignment with international practices was not a major consideration, nor was any friction caused in international economic activities. However, with the conclusion of the transition period associated with China's accession to the WTO, agricultural policymaking is no longer exclusively a domestic matter, as it became necessary to consider international laws, practices, and China's international commitments. China initiated a new round of structural reforms on the supply side of agriculture beginning in 2016, gradually reducing distortions to agricultural production and trade caused by price support policies with "amber box" attributes and exploring a policy-based agricultural insurance system with "green box" attributes in order to comply with WTO rules and increase the quality and efficiency of China's agriculture.

(1) Reducing "amber box" measures: Fine-tuning the minimum purchase price policy

China's minimum purchase price policy is the result of market-oriented reform, providing an important policy tool to ensure that the basic interests of grain farmers through a price floor after the state fully liberalized the domestic grain purchase and sale markets (Ni, 2019). China began to implement a minimum purchase price policy for rice and wheat in 2004.[3] The minimum

[3]China has had a minimum purchase price policy for rice in the main production areas since 2004, while the minimum purchase price policy for wheat was implemented in 2006.

purchase price policy did not receive much attention initially. However, as producer prices in other major grain-exporting countries remained fairly stable, China's cost-based policy purchase price increased as its domestic agricultural production costs rose (Ye, 2020), leading to larger subsidy amounts for China's grain farmers. On the one hand, this has increased the government's fiscal burden; and on the other, the minimum purchase price policy has become the target of accusations from other countries, that have questioned and even sued China for distorting international markets by obstructing other countries' export opportunities.

China began to deepen structural reform on the supply side of agriculture and to actively increase the minimum purchase price policy for rice and wheat under the combined challenges of open market competition and international rules. In light of the importance of rice and wheat to the food supply, China did not abolish the minimum purchase price policy, given its intent to safeguard national food security, but instead made experimental adjustments to the purchase price, purchase volume, and other parameters within the framework of WTO rules. [4]As shown in Figure 6-5, China stopped raising the minimum purchase price of rice and wheat in 2015, dropped the minimum purchase price of early grained rice for the first time in 2016, and began to lower the minimum purchase price of rice and wheat dramatically in 2018. In 2019, after the WTO issued its ruling on the US suit against China for agricultural support policies (case DS511), China, in line with the principle of respecting WTO rules, assessed the Panel report and actively made adjustments within the regulatory framework. China has also changed the total purchase volume under the minimum purchase price policy for rice and wheat, moving from unlimited purchase to limited purchase in 2020.[5] This sequence of actions, it should be noted, reflects China's effort to comply with its international commitments and actively reduce its "amber box" price support policies.

(2) Increasing "green box" measures: Exploring policy-oriented agricultural insurance

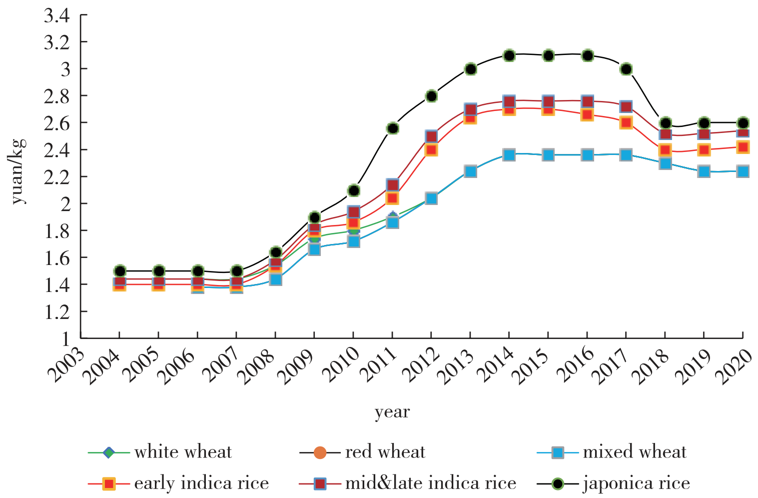
China should implement "green box" food support policies that are not limited by the total amount of subsidy funds in order to support its long-term goal of building a new domestic support and protection policy system that is both appropriate to national conditions and compliant with international rules. Agricultural insurance, a relatively new agricultural policy tool most commonly adopted by developed countries, involves government subsidies and is usually considered a "green box" measure (Roberts, 2005; Mahul and Stutley, 2010). In addition to supporting WTO compliance, promoting agricultural insurance could facilitate the transition of government support for agricultural production from price support policies and direct subsidies to risk management, adding a new lever for guaranteeing food security and safeguarding farmers' interests, and thus is highly valued by China.

The No. 1 Central Document has provided important instructions to expand full-cost insurance and an income insurance system every year since 2016. In 2018, the Ministry of Finance, the Ministry of Agriculture and Rural Affairs, and the CBIRC jointly issued the Notice on the Piloting of Full-Cost Insurance and Income Insurance for the Three Major Food Crops to explore full-cost insurance and income insurance for rice, wheat, and corn through a pilot in 24 large grain-producing counties in six provinces from 2018 to 2020 (see Table 6-2 for the difference between full-cost insurance and income insurance). When the initial pilot expired, the Central Rural Work Conference in 2020 and the No. 1 Central Document in 2021 clearly emphasized the need to continue expanding its scope. Premier Li Keqiang, presiding over an executive meeting of the State Council on June 18, 2021, decided to expand the implementation of full-cost insurance and income insurance for grains in 13 grain producing provinces. With the further opening of China's agriculture sector, full-cost insurance and income insurance can be expected to play an increasingly important role in the process of building a WTO-compliant agricultural support and protection policy system in China.

[4]According to the text of the WTO Agreement on Agriculture, regarding the calculation of MPS (market price support), MPS is calculated as MPS = (AAP-FERP) × Q, where AAP represents the applied administered price, FERP is the fixed external reference price, and Q is the yield that qualifies for the applicable administered price. In China, two possible options to reduce the "amber box" support level of MPS are to reduce the acquisition price and to limit the total amount of acquisitions, as detailed in Wang et al. (2020).

[5] In 2020, China limited the total minimum purchase of rice to 50 million tons (20 million tons for indica rice and 30 million tons for japonica rice) and the total minimum purchase of wheat to 37 million tons.

Figure 6-5 Trends in the Minimum Purchase Price for Rice and wheat in China (2004-2020)



Source: Compiled and produced by the authors based on content released by the National Development and Reform Commission.

Table 6-2 The Main Differences Between Cost Insurance and Income Insurance for Agricultural Products Piloted in China

	Materialized cost insurance	Full-cost insurance	Income insurance
Coverage Level	Coverage for material and service costs	The insurance amount covers the total cost of agricultural production such as material and service costs, labor costs, land costs, etc.	The insurance amount covers the value of agricultural production
Insurance Liability	Yield losses caused by natural disasters, major pests and accidents, etc.		Loss of income due to fluctuations in prices and yields of agricultural products

Note: From the text of the WTO Agreement on Agriculture, although agricultural insurance is classified as "green box" measures not counted toward the total amount of subsidies, it needs to meet a series of strict and quantified preconditions, and agricultural insurance that does not meet the corresponding criteria may still be classified as "amber box" measures.

6.3.2 Potential challenges in the process of exploring China's agricultural support policies

The recent exploration of China's agricultural support policy adjustment is an important guide for building a new system that is adapted to WTO rules. However, these explorations may still face considerable domestic and international pressure as a result of increasingly fierce open market competition and stricter international rules. China must continue to optimize its agricultural support policy system while taking into consideration its national agricultural situation and the reality that agricultural opening will continue.

(1) Possible problems with the adjusted minimum purchase price policy

First, farmers' income from grain cultivation may not be guaranteed under the adjusted minimum purchase price policy. To begin with, the minimum purchase price of grain is determined based on the principle of "production cost plus reasonable profit" or "production cost plus basic income" in China, which is actually the minimum price that guarantees the most basic interests of grain growers. However, as China's minimum purchase price policy for rice and wheat has been undergoing market-based reforms on a trial basis since 2015, the minimum purchase price was significantly reduced in 2018 at the same time that the cost domestic grain cultivation was rising. As a result, the cost of domestic grain cultivation has approached or even exceeded the minimum purchase price in some years, adversely affecting the goal of the minimum purchase price, which is to protect farmers' basic income and guarantee grain security. In other words, when grain prices fall, it may not be possible to avoid the resulting income loss for grain farmers even if the minimum purchase price policy is activated. In addition, although the total acquisitions by volume under China's current minimum purchase price policy could meet the grain farmers' demand for grain sales under current conditions, it is worth considering whether this amount would be sufficient if domestic grain prices fall sharply, and thus whether total acquisitions should be increased or the groups or varieties of acquisitions should be restricted on the basis of limited acquisitions.

Second, minimum purchase price policy adjustments may still face international challenges under trade rules for domestic agricultural support. The WTO Dispute Settlement Body ruling in case DS511 upheld the United States claim regarding the calculation of the subsidy level for China's minimum purchase price policy in 2019. This ruling was extremely disadvantageous for China, as it "locked-in" the scope for future adjustments of the minimum purchase price policy. Given that the minimum purchase price cannot be raised in tandem with the rising cost of producing grain nor can it be significantly reduced, China has begun to set limits on the total amount of purchases. It should be noted that such an adjusted level of subsidies for China's minimum purchase price policy is in line with China's international commitments, but unfortunately, the United States did not recognize China's reform measures and once again resorted to arbitration. [6]

(2) Possible problems for the piloted policy agricultural insurance

First, agricultural insurance subsidies are not ipso facto "green box" measures, and income insurance is more likely to be classified as an "amber box" measure than full-cost insurance. According to the relevant provisions of the WTO Agreement on Agriculture, agricultural insurance subsidies can only be considered as "green box" measures if they meet strict preconditions. In theory, through reasonable mechanism design, both government subsidies for full-cost insurance and income insurance may be considered as "green box" policies not counted toward the total amount of subsidies. But in practice, subsidies for income insurance qualify as "green box" policies only under strict conditions. The WTO rules not only draw quantitative distinctions between insurance compensation conditions and compensation amounts for full-cost insurance and income insurance subsidies that can be regarded as "green box" policies, but also differentiate between the insurance objects of the two: No provision requires full-cost insurance to be tied to a specific crop, whereas income insurance must be decoupled to a specific crop, i.e., "The amount of any such payments shall relate solely to income; it shall not relate to the type or volume of production (including livestock units) undertaken by the producer." While the full-cost insurance for staple grains piloted in China generally meets the standards and conditions of a "green box" measure, the piloted corn income insurance is limited to the type of production, thus the subsidies provided by the government are likely to be considered a product-specific "amber box" policy (Zhu, et al., 2020). Based on the existing price support policies for rice and wheat, China would face challenges under WTO rules if it implements further subsidies for agricultural income insurance.

Second, there is an overlap between income insurance and minimum purchase price policy in terms of the price insured function. Income insurance, an advanced form of agricultural insurance that can "protect prices and income," can protect against the risk of natural disasters in agricultural production as a cost insurance and protect against the risk of market changes. However, China continues to implement the minimum purchase price policy in the main grain-producing provinces, and the market risk faced by rice and wheat producers remains relatively limited as long as the market price is underpinned by the minimum purchase price. In other words, if China implements income insurance for rice and wheat, it is possible that the minimum price support will prevent falling prices from reducing farmers' income enough to trigger the payment of compensation; that is, the "price insurance function" will not be activated, and income insurance will not play its potential role in reducing income risk from market changes. While the minimum purchase price policy remains in use, the preferable option for China is probably to implement full-cost insurance for rice and wheat.

Based on the above analysis, it is clear that the practical exploration of China's agricultural support

[6] For detailed information, see the WTO website https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds511_e.htm.

policy for reducing "amber box" and increasing "green box" measures has had some achievements and provided valuable experience for further transformation and upgrading, but still faces substantial challenges from both import competition and international rules. On the one hand, the minimum purchase price policy, as an important tool to guarantee domestic grains security, should not be abolished for the time being, but does need to be further adjusted and improved to resume its price floor function; on the other hand, agricultural insurance, as a market-based risk management tool, will play an important role in the construction of China's new agricultural support policies. It is worth noting that there is a significant difference in operability between the two measures classified as "green box" — the full-cost insurance subsidy and the income insurance subsidy. From the perspective of adapting to WTO domestic support rules, since the minimum purchase price policy for rice and wheat occupies the "amber box" support space for most of the specific products, China should provide government subsidies to rice and wheat through operable full-cost insurance, which is classified as a "green box" measure. In addition, from the perspective of farmers' demand, rice and wheat producers are more willing to take out natural disaster risk insurance under the protection of the minimum purchase price policy. The coverage amount of full-cost insurance is also significantly higher than the traditional materialized cost insurance, which can effectively meet the needs of rice and wheat producers. Therefore, at this stage, it is recommended that China promote the transition and upgrading of domestic agricultural policy design within international rules with an institutional design that both continues to improve the minimum purchase price policy for rice and wheat and implements full-cost insurance for rice and wheat.

6.4 Simulation analysis of the economic impact of China's agricultural support policy transformation program

As the most populous developing country in the world, it is important to ensure that China's rice bowl is kept firmly in the people's hands. China's agricultural support policies must be adjusted to the constraints of international trade rules while simultaneously ensuring that the interests of grain farmers are not compromised, that fiscal spending remains efficient, and that the domestic food supply and demand balance system does not suffer major shocks. To examine the possible options for the grain support policies discussed above, this chapter considers four specific simulation scenarios for rice and wheat. These are used to explore the economic impacts of the possible transformation scenarios for China's agricultural support policies that result from "reducing 'amber box' measures and increasing 'green box' ones." These scenarios project the possible impacts of the adjustment of the minimum purchase price policy for rice and wheat and the implementation of the agricultural insurance policy on farmers' welfare, government fiscal expenditure efficiency, and food trade, to support selection of the optimal agricultural support policies that can both comply with international rules and take into account domestic realities.

6.4.1 Simulation scenario setting

Considering the practical exploration of China's agricultural support policy for "reducing 'amber box' measures and increasing 'green box' ones" and the subsequent challenges that may be faced, this chapter sets up four policy adjustment simulation scenarios for rice and wheat based on the comprehensive consideration of the adaptation conditions for the minimum purchase price policy and agricultural insurance policy, with 2019 as the base year (see Table 6-3). Scenarios 1–3 consider the combined effect of minimum purchase price policy and cost insurance policy, [7] while Scenario 4 considers the effect of cost insurance policy. In Scenario 3, this chapter refers to the study of Cao et al. (2017) and sets the reduction in the minimum purchase price at 4.7 percent for rice and 8.5 percent for wheat, so that it is close to the average total production costs in the main producing provinces where

[7] The simulation scenario in this chapter does not include the combination of minimum purchase price policy and income insurance policy. On the one hand, the "price protection function" of income insurance may overlap with the minimum purchase price policy; while on the other hand, the single species income insurance subsidy is more likely to be regarded as an "amber box" measure, and the income insurance subsidy combined with the minimum purchase price policy for rice will inevitably generate a combined support volume that exceeds the total amount of China's WTO accession commitments.

Table 6-3 Design of a Simulation scenario for the Transformation of Agricultural Support Policies for Rice and Wheat in China

	Rice	Wheat
Baseline scenario	No change in minimum purchase price	
Scenario 1	No change in minimum purchase price + Materialized cost insurance	
Scenario 2	No change in minimum purchase price + Full-cost insurance	
Scenario 3	Minimum purchase price reduced by 4.7% + Full-cost insurance	Minimum purchase price reduced by 8.5% + Full-cost insurance
Scenario 4	Full-cost insurance instead of minimum purchase price	

Note: The minimum purchase price of rice adopts the average minimum purchase price of early indica rice, medium indica rice, late indica rice and japonica rice; the minimum purchase price of wheat adopts the average minimum purchase price of white wheat, red wheat and mixed wheat. To facilitate the comparison of simulation results, this chapter only considers the cost insurance under the 100% coverage level.

the minimum purchase price policy for rice and wheat was implemented in 2019.

After defining the simulation scenarios, this chapter uses the parametric method to fit the unit yield and price data of the two crops, based on historical data for rice and wheat from 1990 to 2019. Ten thousand sets of possible unit yield–price data pairs for rice and wheat, using 2019 as the examination period, are generated by employing the Copula theory and Monte Carlo stochastic simulation method based on the fitting function. Then the minimum purchase price policy and agricultural insurance policy are modelled; that is, the chapter takes the pseudo-random numbers generated above into the different agricultural support policy transformation scenarios based on the expectation effect theory, and simulates and analyzes the possible impacts of the different agricultural policy transition scenarios on farmers' welfare and government fiscal expenditure via a simulation approach, and then discusses the possible resulting trade impacts. [8]

6.4.2 Analysis of the simulation results of agricultural policy transformation schemes for farmers' welfare and government expenditure efficiency

Both the minimum purchase price policy and the agricultural insurance policy can effectively protect farmers' grain cultivation income and increase their incentive to grow grain. However, there are differences in the extent to which the two policies can protect farmers' income, given the same fiscal expenditure. Determining which policy option is preferable for China requires an analysis of the possible implementation effects of different options.

(1) Impact on farmers' economic welfare

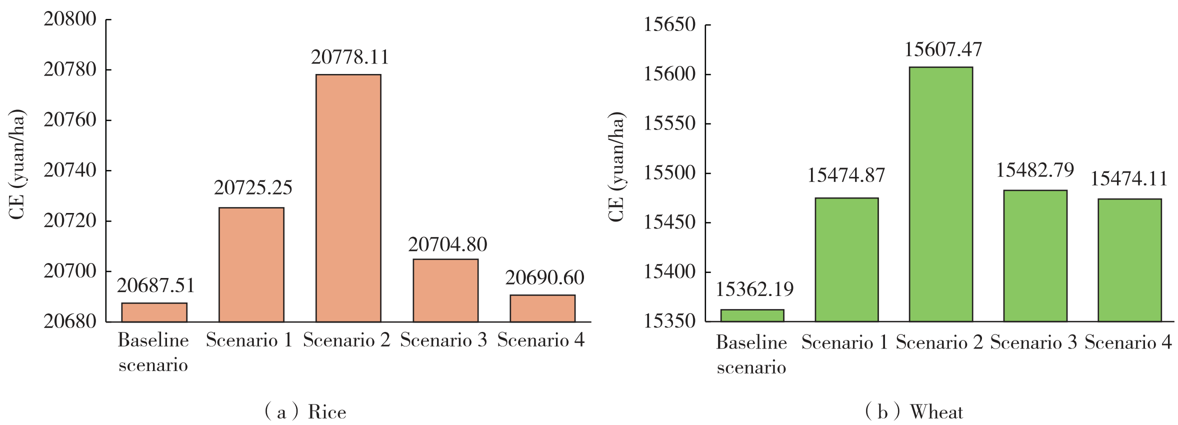
The simulation results show that (1) reducing the "amber box" measures and increasing the "green box" measures in agricultural support policies for rice and wheat does not harm farmers' economic welfare, [9]but rather improves their welfare to varying degrees, and that (2) the policy combination of the minimum purchase price and cost insurance improves farmers' economic welfare more than a single policy. The results are shown in Figure 6-6. First, comparing Scenarios 1 and 2 with the baseline scenario shows that, when the current minimum purchase price remains unchanged, the implementation of overlapping cost insurance for rice and wheat in China can effectively help rice and wheat farmers to protect themselves against the risk of yield fluctuations and thus improve their economic welfare, while full-cost insurance

[8]The general equilibrium or partial equilibrium analysis is not used here because we are currently not able to introduce full-cost insurance policies into equilibrium models.

[9] In this chapter, the Von Neumann–Morgenstern (V-N-M) expectation effect function is used to measure the level of utility brought on by different agricultural support policy adjustment scenarios to farmers, and certainty equivalence (CE) is used to compare the change in farmers'' economic welfare in the risky state. $U=1/(1-\gamma)W(1-\gamma)$, where U represents the effect level of farmers, W represents the income received by farmers in the risky state, and γ represents the relative risk aversion coefficient of farmers. $\gamma > 1$ indicates that farmers are risk averse.

can have a greater impact on farmers' economic welfare because its coverage is significantly higher than the materialized cost insurance. Second, the comparison of Scenarios 3 and 4 with Scenario 2 indicates that, under the premise of full-cost insurance for rice and wheat, reducing the minimum purchase price for rice and wheat could lead to a decline in farmers' economic welfare, while directly eliminating the minimum purchase price policy could lead to a further decline in farmers' economic welfare, but the magnitude of the further decline is relatively small. This may be because Scenario 3 reduces the minimum purchase price to a level that protects farmers' agricultural production costs. In the realistic context of total agricultural production costs gradually approaching output value, the return of the minimum purchase price to a floor price function no longer has an obvious market support effect, and thus its effect differs little from the abolition of the minimum purchase price. Overall, when the minimum purchase price policy is still applicable, the implementation of the materialized cost insurance policy and the full-cost insurance policy can both improve farmers' economic welfare compared to the baseline scenario. This is mainly because the minimum purchase price policy is equivalent to no-cost price insurance for farmers, while the combination of the minimum purchase price policy and full-cost insurance protects farmers from both natural disaster risks and market change risks, and thus the effect of the policy combination is more significant than that of a single policy.

Figure 6-6 The Impacts of Agricultural Support Policy Transformation Scenarios for Rice and Wheat on Farmers' Economic Welfare



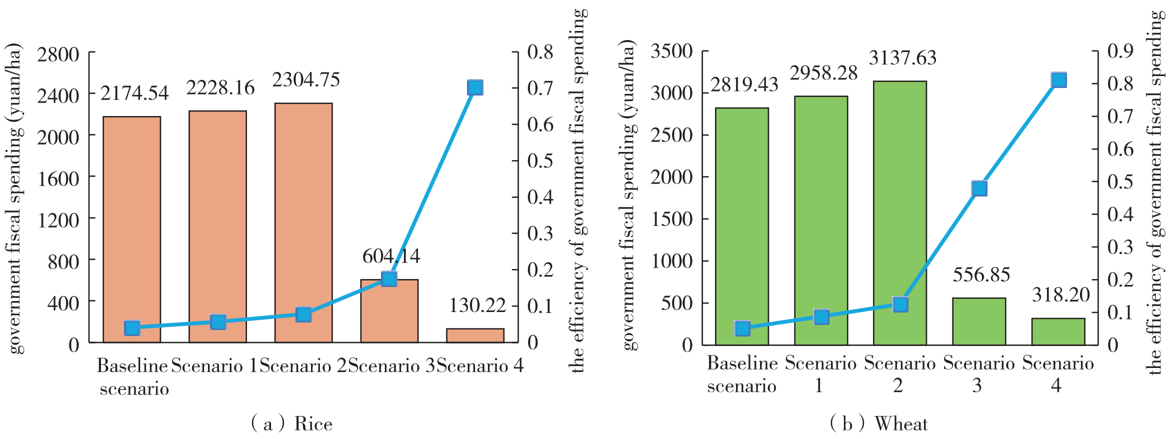
Note: To facilitate a comparison of the impact of different policy schemes on farmers' economic welfare, this chapter takes γ as 2 for analysis referring to the study of Wang et al. (2018).

(2) Impact on the efficiency of government fiscal spending

The simulation results show that reducing the "amber box" measures and increasing the "green box" measures in China can significantly improve the government's fiscal spending efficiency for agricultural support policies for rice and wheat, and that the government's fiscal spending efficiency for cost insurance is significantly higher than the minimum purchase price policy.[10] The results are shown in Figure 6-7. First, from the perspective of the amount of government fiscal expenditure, comparison of the four scenarios shows that increasing the guarantee level of cost insurance (upgrading the materialized cost insurance to full-cost insurance) does not increase the government's fiscal expenditure significantly, while reducing the minimum purchase price reduces fiscal expenditure significantly. Taking rice as an example, the government's financial expenditure only increases from 2,228.16 yuan to 2,304.75 yuan when materialized cost insurance (Scenario 1) is upgraded to full-cost insurance (Scenario 2). In contrast, the government's fiscal expenditure falls from 2304.75 yuan to 604.14 yuan and 130.22 yuan, respectively, a large reduction of 73.79

[10] Efficiency in government fiscal expenditure refers to the ratio of the increase in the welfare gained by farmers per policy transformation program compared to the welfare of farmers under the no policy intervention program to the government expenditure of the corresponding program.

Figure 6-7 Impact of Agricultural Support Policy Transformation Scenarios for Rice and Wheat on Government Fiscal Expenditure Efficiency



Note: Government fiscal expenditure efficiency refers to the ratios of farmers' welfare obtained by the five types of policy transformation programs to the corresponding government expenditures.

percent and 94.35 percent when the minimum purchase price for rice is lowered by 4.7 percent (Scenario 3) or abolished completely (Scenario 4). [11] The main reason for these differences is that the government's intervention in the agricultural insurance market through premium subsidies effectively has the leverage effect of financial subsidies, while the acquisition funds of the minimum purchase price policy are all covered by government financial expenditures. In addition, this verifies that the implementation of the minimum purchase price policy, which is considered an "amber box" measure, is the prime cause of current high fiscal expenditure.

Second, from the perspective of fiscal expenditure efficiency, the combination of implementing the minimum purchase price policy for rice and wheat and increasing the guarantee level of cost insurance increases the government's fiscal expenditure to some extent, but the government's fiscal expenditure efficiency can be improved, as shown by the results of Scenarios 1 and 2. In addition, if China were to eliminate the minimum purchase price policy for rice and wheat and implement full-cost insurance, the efficiency of fiscal spending could be significantly improved. Finally, implementation of an agricultural insurance policy would mean that the government only needs to provide a fixed premium subsidy annually which, compared with the price support policy, can help the government stabilize inter-annual expenditures.

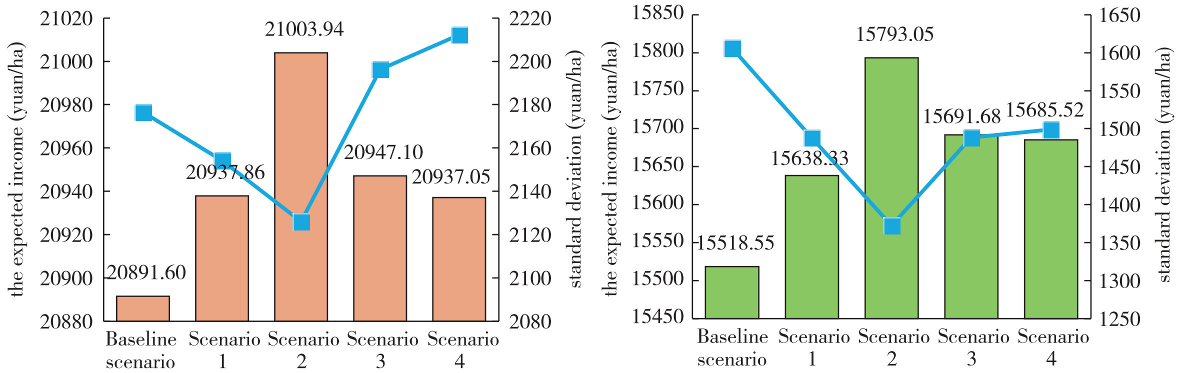
6.4.3 Discussion on the possible impact of agricultural support policy transformation schemes on grain trade

This chapter, limited by the simulation method, cannot derive the direct impact of China's various agricultural support policy adjustment schemes on the grain trade. Based on the simulation results regarding the different agricultural support policy transformation programs, this chapter discusses the potential impacts of the five scenarios on China's grain trade.

From the perspective of agricultural production, the amount of farming income directly affects farmers' motivation to grow grain, which in turn affects grain production. The simulation results in this chapter show that reducing "amber box" measures and increasing "green box" measures in China's agricultural support policy does not cause a large impact on the expected income of either rice or wheat growers. First, as shown in Figure 6-8, the expected income of farmers does increase when China upgrades materialized cost insurance (Scenario 1) to full-cost insurance (Scenario

[11] Based on the actuarial theory of premiums, this chapter uses the national level data with gentler fluctuations to measure the gross cost insurance rates of 0.90% and 2.62% for rice and wheat, respectively, while in practice, the cost insurance rates obtained by measuring based on provincial, municipal, or county-level unit production data may not be too low, so the degree of the decline in government's fiscal expenditure may not be as large as shown in the figure.

Figure 6-8 Impact of Transformation Scenarios for Agricultural Support Policies for Rice and Wheat on Farmers' Expected Income from Cultivation

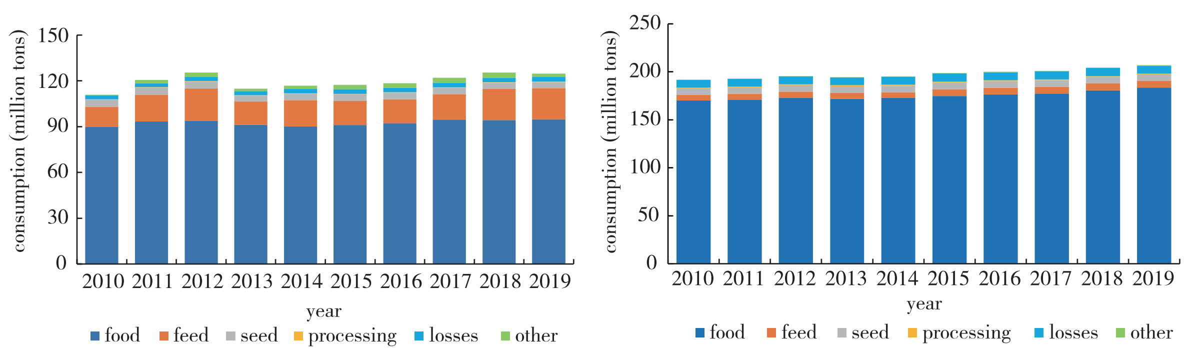


(a) Rice (b) Wheat

2), meaning that the adjustment of China's agricultural support policies for rice and wheat toward more "green box" measures does not harm farmers' incentive to grow grain. Second, even under the scenarios in which China reduces or even eliminates the minimum purchase price policy for rice and wheat and implements a full-cost insurance policy (Scenario 3 and Scenario 4), the maximum reduction in farmers' expected income, compared to Scenario 2, is only 0.32 percent for rice growers and 0.68 percent for wheat growers. The overall support level differs little from China's current policy combination of materialized cost insurance plus minimum purchase price. Based on Nerlove's (1956) theory of supply and demand of agricultural products, this also means that reducing "amber box" measures in China's agricultural support policy for rice and wheat will not significantly reduce farmers' incentive to grow rice and wheat, and grain production can be effectively guaranteed.

From a trade perspective, the demand for food imports is the result of a combination of domestic production and consumption. China's current consumption demand for rice and wheat is growing at a low rate, although it is continuously expanding (Du, 2020). As shown in Figure 6-9, China's consumption of rice and wheat increased from 191.69 million tons and 111.02 million tons to 206.79 million tons and 124.72 million tons, respectively, with average annual growth rates of only 0.85 and 1.30 percent from 2010 to 2019. With the slowing growth of China's population and improving diets, the total domestic consumption demand for rice, wheat, and other staple grains is reaching its peak. This also means that, given little change in domestic consumption, as long as the adjustment of domestic agricultural support policies to reduce "amber box" and increase "green box" measures does not impact

Figure 6-9 The Consumption of Rice and Wheat in China from 2010 to 2019



(a) Rice (b) Wheat

Source: FAO balance sheet.

grain production substantially, China's demand for imported grain is not expected to rise significantly. The international trade of rice and wheat still belongs to the category of transfer between varieties.

6.5 Conclusion and recommendation

Based on a brief analysis of the exploration of policy practices and possible challenges for China's domestic agricultural support policies that reduce "amber box" and increase "green box" measures, this chapter simulates and analyzes the impact of potential policy options on farmers' welfare, the efficiency of government fiscal spending, and grain trade in China in the future. The simulation results show that the current combination of minimum purchase price policy plus full-cost insurance maximally raises farmers' economic welfare, but also increases the government's financial burden. In addition, in the scenario of reducing the minimum purchase price to guarantee the total cost of agricultural production plus the implementation of full-cost insurance, the economic welfare of farmers does not suffer a large loss and the government's fiscal spending efficiency can be improved significantly, while national food security is not significantly affected. In addition, this study, tackling the possible impacts of different policy transition options on China's grain trade, concludes that if domestic consumption is relatively stable, China's demand for external grain sources will not rise significantly, and trade in rice and wheat between China and the world grain market will continue to consist primarily of inter-varietal transfers, given that the impact of the various policy scenarios on the expected income of rice and wheat farmers is relatively limited and that grain production is expected to be relatively stable. This chapter draws the following policy recommendations:

Above all, China must continue to actively promote domestic agricultural support policies that reduce "amber box" and increase "green box" measures, and explore innovative subsidies within the scope of the rules. One is to lower the minimum purchase price for rice and wheat gradually to bring it down to the cost of grain production, gradually shifting the function of the minimum purchase price policy from market-support to a price floor. Second is to implement a complementary full-cost insurance, which is more likely to be regarded as a "green box" measure than income insurance. The combination of the two policies can safeguard farmers' welfare and improve the efficiency of government fiscal spending.

Moreover, while adapting to the transformation and trade rule constraints, domestic agricultural support policies must adjust the direction of agricultural support policies and objectives of national food security; that is, moving from a focus on immediate high grain production and high rate of self-sufficiency toward the pursuit of sustainable agricultural development and long-term food security. First, the cost of agricultural production can be reduced through financial support to drive the consolidation of farming lands, promote scientific and technological progress, and increase investment in infrastructure. And second, promoting the transformation and upgrading of domestic agriculture from yield-oriented to quality- and competitiveness-oriented through agricultural support policies to create a competitive domestic food production and supply system.

In addition, by actively participating in the negotiation and formulation of international rules, China can promote and lead WTO reform and the reshaping of international rules. Looking forward, China needs to more actively promote agricultural reform under the WTO framework and build new international rules, rather than accepting domestic realities and the established system of international rules. The inequities in WTO rules for domestic agricultural support between developed and developing countries should be rectified in subsequent negotiations. At the same time, China needs to play a role in issues such as public food security reserves and agricultural trade to help create a sound international order.

Last but not least, it is necessary to note that this chapter uses a simulation approach based on historical data to measure and analyze the potential impacts of the agricultural support policy adjustment schemes that reduce "amber box" and increase "green box" measures on farmers' welfare, government spending efficiency and food trade. This simulation method has some limitations. The analysis thus fails to endogenize the minimum purchase price policy with the agricultural insurance policy, meaning that the magnitude of the specific simulation results may deviate from the real situation. Theoretically, agricultural insurance as a market-based risk management tool plays a role in reducing the volatility of farmers' income and improving the efficiency of the government's fiscal spending. The simulation results in the chapter verify this point; that is, the directionality of the results is correct and still has certain reference significance. As the process of agricultural support policy adjustment and the agricultural insurance program in China continue to advance, future studies will focus on constructing equilibrium models to assess more comprehensively the potential impacts of different agricultural support policy combinations.

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