



CHINA AND GLOBAL FOOD POLICY REPORT 2023

PROMOTING SUSTAINABLE HEALTHY DIETS FOR TRANSFORMING AGRI-FOOD SYSTEMS



Academy of Global Food Economics and Policy
Address: No.17 Qinghua East Road, Haidian District, Beijing, China
Tel: +86 10 6273 7177
E-mail: agfep@cau.edu.cn



China Academy for Rural Development, Zhejiang University
Address: Chuangyi Building A, Zijingang Campus, Zhejiang University,
No.866 Yuhangtang Road, Hangzhou, Zhejiang, China
Tel: +86 571 8898 1522
E-mail: cardzu@zju.edu.cn



National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention
Address: No.27 Nanwei Road, Xicheng District, Beijing, China
Tel: +86 10 6623 7298
E-mail: ccdcnutrition@ninh.chinacdc.cn



Centre for International Food and Agricultural Economics, Nanjing Agricultural University
Address: The Third Laboratory Building of Nanjing Agricultural University,
No.1 Weigang, Xuanwu District, Nanjing, Jiangsu, China
Tel: +86 25 8439 5741
E-mail: CIFAE@njau.edu.cn



International Food Policy Research Institute
Address: 1201 Eye Street, Washington, DC 20005 USA
Tel: +1 (202) 862-5600
E-mail: ifpri@cgiar.org



Food and Land Use Coalition
Address: Rm K-M, 7/F, Tower A, The East Gate Plaza, #9 Dongzhong Street, Beijing, China
Tel: +86 10 6416 5697
E-mail: haijun.zhao@wri.org



World Resources Institute
Address: Rm K-M, 7/F, Tower A, The East Gate Plaza, #9 Dongzhong Street, Beijing, China
Tel: +86 10 6416 5697
E-mail: xiaotian.fu@wri.org

Academy of Global Food Economics and Policy, China Agricultural University (AGFEP)
China Academy for Rural Development, Zhejiang University (CARD)
National Institute for Nutrition and Health (NINH) of the Chinese Center for Disease Control and Prevention (China CDC)
Centre for International Food and Agricultural Economics, Nanjing Agricultural University (CIFAE)
International Food Policy Research Institute (IFPRI)
Food and Land Use Coalition (FOLU)
World Resources Institute (WRI)



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AGFEP

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Foreword I

Since the reforms and opening up, China's economy and society have continued to develop rapidly; the income level of urban and rural residents has continuously grown, the dietary structure of residents has gradually diversified, and dietary energy intake has increased. However, the issue of residents' unbalanced dietary structure and nutritional intake is becoming increasingly prominent, leading to an upward trend in the incidence of nutrition-related chronic diseases and bringing new challenges to the sustainability of resources and the environment. If no measures are adopted, the realization of the strategic goals of "Healthy China 2030" and the country's sustainable development will be constrained. In 2019, the EAT-Lancet Commission first published the EAT-Lancet report, the first scientific elaboration of healthy diets based on sustainable food production systems. In the same year, the Food and Agriculture Organization of the United Nations and the World Health Organization also formulated guidelines for sustainable and healthy diets. Nevertheless, these discussions remain at the global level and have limited significance in guiding the dietary patterns of Chinese residents. Therefore, there is an urgent need to conceptualize a sustainable and healthy dietary pattern suitable for Chinese residents and China's natural resources endowment.

To this end, the Academy of Global Food Economics and Policy (AGFEP) of China Agricultural University (CAU), led by Professor Fan Shenggen, has published 2023 China and Global Food Policy Report (in both English and Chinese) in collaboration with several domestic and international institutions. Adhering to an international perspective and using case studies and data from China, this report focuses on systematic research into the following topics: healthy diets for Chinese residents, the environmental impacts of Chinese diets, impacts of international trade and overseas investment on residents' dietary patterns, and interventions to change residents' food consumption behaviors. The purpose is to help promote Chinese residents' dietary transformation for improving both population's health and environmental sustainability. This is another instance where AGFEP has conducted systematic research for major national need and released another flagship report after 2021 and 2022. The report has attracted widespread attention and inspired discussion among policymakers and researchers worldwide.

The 2023 report points out that China must adopt healthy diets suitable for Chinese residents, formulate a sustainable and healthy diet as guidance by region, use international trade and investment to improve diets of residents, establish a concept of a sustainable healthy diet for all, and guide residents' food consumption toward a sustainable and healthy pattern through the popularization of "food education." This will contribute to achieving the goals of the "Healthy China 2030" plan. The report fully embodies the characteristics of multidisciplinary cross-sectional research, providing a decision-making reference to promote the dietary transformation of its population and presenting a Chinese solution for the transformation to globally sustainable and healthy diets. In the future, CAU will continue to be guided by China's major strategic needs, fully leverage the advantages and characteristics of multidisciplinary and cross-sectional research teams, and conduct emerging and cutting-edge research on agriculture. Further, it will better serve national multidimensional development strategic goals such as food security, national nutrition and health, green and low-carbon development, and rural revitalization and will contribute the wisdom of CAU to the development of a strong agricultural country.

Sun Qixin

President, China Agricultural University





Foreword II

The report of the 20th National Congress of the Communist Party of China proposed to accelerate the building of a strong agricultural country, comprehensively strengthen the foundation of food security, and ensure that the Chinese people firmly hold the bowl of food in their own hands. Building a strong agricultural sector serves as the foundation for building a modern socialist country. Furthermore, the development of agriculture is essential for meeting the people's needs for a better life, achieving high-quality development, and consolidating national security. In the current challenging international situation, it is essential to safeguard the foundation for the development of agriculture and secure the "ballast" of responding to new situations to solve fundamental issues related to agriculture, rural areas, and farmers.

Since the reform and opening up, China has made significant achievements in ensuring food security and supply. It has lifted approximately 800 million people out of absolute poverty and secured their basic needs. Furthermore, it has shifted its citizens' goals in food consumption from "having enough food" to "having salubrious diets." Moreover, the demand for diversified food consumption has further increased. However, challenges remain with regard to food supply and security. First, the structure of food supply is unbalanced. China has attained self-sufficiency and a surplus of grain supply; however, supply gaps exist vis-à-vis other products such as feedstock, cooking oil, sugar, meat, and milk. Moreover, the insufficient supply of high-quality domestic agricultural products, underdeveloped food processing industry, and inadequate food supply cannot meet the citizens' needs for upgrading consumption. Second, the imbalanced dietary structure of the citizens has affected their nutritional health and created tremendous pressure on food production, resources, and the environment.

Looking to the future, China's food demand stands to further undergo profound transformations both in terms of quantity and structure. Although the aggregate demand for staple food will gradually decrease, the appetite for high-quality protein-based foods will increase, which will put further pressure on the environment and resources. Therefore, a transformation in food supply and consumption patterns is urgently needed in China to establish a nutritionally healthy and environmentally sustainable food production and consumption model. Against this backdrop, the 2023 China and Global Food Policy Report has been released by the research group at the Academy of Global Food Economics and Policy of China Agricultural University, led by Professor Fan Shenggen, in collaboration with multiple Chinese and international research institutions. Under the theme of "Promoting Sustainable and Healthy Diets to Facilitate the Transformation of Agricultural and Food Systems," this report is timely and farsighted. Furthermore, it echoes the "advocacy for healthy diets" highlighted in the Number One Central Policy Document of 2023.

Based on data and models, this report examines various topics, with a focus on the healthy dietary structure of people in China, sustainable dietary patterns, impacts of international agricultural trade and investment on dietary pattern, and interventions on changing food consumption behavior. The report reflects the characteristics of interdisciplinary, multisectoral, and international perspectives in addition to their close integration with Chinese practices. Additionally, the report proposes several recommendations, such as establishing a healthy dietary pattern suitable for Chinese citizens, formulating region-specific guidance on sustainable and healthy diets, improving diets via trade and foreign direct investment, and steering the dietary transformation through multipronged interventions. These suggestions offer vital insights for decision makers, researchers, industry personnel/professionals, and consumers. The publication of the report will contribute to promoting positive dietary transformation and facilitating the transformation of agrifood systems toward the multidimensional goals of green, low-carbon, high-quality, efficient, resilient, and inclusive agriculture as well as nutritious and healthy diets. Furthermore, it will facilitate the efforts geared toward aspirations for a better life.

Qian Keming

Former Vice Minister of Commerce and Senior Research Fellow at the Chinese
Academy of Agricultural Sciences





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Executive Summary

The current situation of global food and nutrition security is increasingly worrisome, and it is unfortunate that progress in eliminating hunger, food insecurity, and multiple forms of malnutrition has been hindered or even reversed by recent global events. It is estimated that globally, 702 million to 828 million people (8.9 to 10.5 percent) suffered from hunger in 2021, with 150 million added during the COVID-19 pandemic. Approximately 2.3 billion people are in a state of moderate or severe food insecurity, with 11.7 percent facing severe food insecurity. Nearly 3.1 billion people could not afford a healthy diet, which is an increase of 112 million from the last year. The causes of food insecurity are multifaceted, including the impact of the COVID-19 pandemic, the crisis in Ukraine, and climate change. Simultaneously, income levels have been adversely affected, and prices have risen, reducing people's ability to purchase food and making it unaffordable. Therefore, it is imperative for governments and other stakeholders to act collectively to improve the state of global food and nutritional health.

Many countries, including China, have begun to pay more attention to the issue of agrifood systems and are proposing a transition to the multidimensional goals of nutrition and health, green and low-carbon, efficiency, resilience, and inclusiveness. At the international level, a series of high-level international conferences and action plans, such as the UN Food Systems Summit, the Nutrition for Growth Summit, and UN Climate Change Conference (COP26) in 2021 and COP27 in 2022, have demonstrated the importance and urgency of promoting the transformation of agrifood systems. These conferences advocated for countries to work together to transform the way food is produced and consumed to build healthier, sustainable, and equitable food systems. At the domestic level, China has always regarded food security as a top priority for national development. In 2022, the total annual national grain output reached 686.53 million tons and has remained stable for eight consecutive years at more than 650 million tons. In 2022, the Chinese government emphasized the need to "establish a big food concept" and "strengthen the foundation of food security in all aspects" from the perspective of putting people first and better meeting their increasingly diversified food consumption needs. In light of the various risks and challenges posed by the contemporary era, safeguarding food security necessitates a shift from a narrow focus on food production to a more comprehensive consideration of the entire food supply chain. This entails promoting the development of a diversified food supply system and expanding the focus from mere quantity to encompassing multiple objectives related to the "quantity, structure, and quality" of food. Such an approach will serve to bolster the foundations of food security on all fronts.

In the past, international and domestic attention focused more on food supply, but with insufficient attention paid to consumption. However, the consumption side, especially the dietary structure of residents, is closely intertwined with nutrition, health, resources, and the environment. Current dietary patterns around the world and in most regions are neither healthy nor sustainable. In terms of nutrition, a quarter of adult deaths worldwide are attributed to poor diets, which are low in fruits, vegetables, nuts, and whole grains and high in ultra-processed foods, red and processed meats and sugary drinks. In terms of resources and the environment, food systems as a whole account for more than one-third of global greenhouse gas (GHG) emissions and use a large and growing amount of environmental resources, including land, water, and fertilizers containing nitrogen and phosphorus. There are multiple challenges to the current diets of Chinese people. On the one hand, diets increased total energy's intake and result in people's being overweight and obese. Chinese people's intake of edible oil and salt is relatively high, while their intake of whole grains, dark green vegetables, fruits, dairy, fish and shrimp, and soybeans is generally insufficient. On the other hand, high input-driven agriculture and food production, distribution (storage, processing, transportation), and consumption are environmentally costly and unsustainable. For example, excessive use of chemical inputs has caused severe soil contamination and degradation of the land; more than two-thirds of arable land in China is considered to be of relatively low quality. Therefore, considering the negative impacts of the current agrifood system on resources



and the environment, and the nutritional and health concerns caused by unbalanced diets, there is an urgent need to promote healthy diets with low environmental footprints.

Sustainable and healthy diets were proposed by the EAT Lancet Commission in 2019, advocating for the integration of healthy and sustainable diets into the same framework. However, what sustainable and healthy diet models are suitable for the Chinese population and the current agrifood situation? How can sustainable and healthy dietary patterns be promoted? These are the issues this report will focus on. This report is jointly published by the Academy of Global Food Economics and Policy of China Agricultural University in collaboration with the China Academy for Rural Development of Zhejiang University; the National Institute for Nutrition and Health of the Chinese Center for Disease Control and Prevention; the Centre for International Food and Agricultural Economics of Nanjing Agricultural University; and the International Food Policy Research Institute and the Food and Land Use Coalition, and World Resources Institute.

The 2023 report builds on the 2021 and 2022 reports regarding the direction and path of the transformation of the agrifood system and reform of agricultural support policies and further investigates China's sustainable and healthy diet models in the new era. This report is oriented toward the diversified development goals of the transformation of the agrifood system and focuses on conducting in-depth research on sustainable and healthy dietary patterns in China. Based on cross-sectoral and multidisciplinary collaborative research, the report highlights the close integration of international perspectives and Chinese practices related to sustainable and healthy diets and aims to provide policymakers, researchers, and practitioners of the agrifood system with systematic, scientific, and cutting-edge references for decision making and research.

Chapter 1 of the report systematically reviews the progress of international research on sustainable and healthy diets, analyzes the current situation of Chinese residents' diets and the main problems faced in the transformation to sustainable and healthy diets, and proposes policies and actions. Chapter 2 summarizes the impact of the current dietary imbalance on chronic diseases; analyzes the intake of different food categories, macronutrients, and micronutrients across different regions of China; and then presents reflections on the dietary patterns consistent with nutrition and health in China. Chapter 3 evaluates and analyzes the environmental impact of food consumption in various regions, simulates and analyzes changes in the environmental impact of different food consumption choices in the context of regional food resources, and discusses sustainable and healthy dietary patterns. Chapter 4 analyzes the current situation and trend of global agricultural trade and investment, reviews the paths of international trade and investment affecting dietary patterns, and empirically analyzes the impact of trade opening and the expansion of Western-style fast-food chains on consumption and nutritional status of Chinese residents. Chapter 5 conducts a systematic review and analysis of the limiting factors of consumers' dietary behavior transformation and the effects of different types of intervention programs to explore how sustainable and healthy dietary choices can be promoted through interventions targeted at consumers.

The key findings

First, there is high global consensus on the importance and urgency of shifting to sustainable and healthy diets. Sustainable and healthy diets will reduce risks both of being overweight and obese and of chronic diseases and cognitive disorders while reducing environmental impacts in terms of GHG emissions, water and land use, and nitrogen and phosphorus emissions. However, the current diets of Chinese residents are neither healthy nor sustainable, and there is an urgent need to promote the transition to sustainable and healthy diets.

Second, increasingly imbalanced diets of the Chinese population has caused nutritional and health problems that require close attention. Unbalanced diets lead to a rise in the risk both of being overweight or obese and of the onset of chronic diseases and morbidity; such diets are reflected in the insufficient intake of dietary fiber, vitamin A, calcium, and zinc throughout the country. The current dietary guidelines in China lack systematic consideration of the research on the Chinese population and residents' dietary habits, and there is an urgent need to propose reforms and optimizations.



Third, current food consumption of Chinese residents imposes tremendous pressure on resources and the environment. Carbon emissions from total food consumption are estimated to increase from 1.18 billion tons in 2020 to 1.28 billion tons in 2030. Combining global food resources, reducing grain consumption reasonably, increasing fruit consumption, substituting meat consumption with soybean consumption, or adjusting the structure of meat consumption can significantly reduce pressure on the environment.

Fourth, global trade and investment in agriculture and food have affected the dietary consumption structure of Chinese residents. In the past 20 years, the trade of agricultural products between China and the rest of the world has reflected a steadily growing trend. Under the influence of international trade and investment, Chinese residents have increased the ratio of fat and protein in their energy supply mix and increased their consumption of sugary beverages, thereby raising the risk of obesity.

Fifth, a sustainable and healthy dietary transition requires effective intervention programs based on barriers to transition, goals, and target characteristics. A range of strategies such as information dissemination, behavioral interventions, economic incentives, and supportive policies can help drive behavioral transformation. Simultaneously, interventions should pay greater attention to the applicability and effectiveness of the programs and focus on specific groups and scenarios.

In the global context, promoting the transformation of sustainable and healthy diets in China requires fourfold efforts: first, establish healthy diet models suitable for Chinese population; second, propose an optimized plan for a sustainable and healthy diet; third, adjust international trade and overseas investment to improve residents' diets; and fourth, intervene through multiple instruments to guide residents' sustainable healthy diet changes.

Specific recommendations

First, the national dietary guidelines should be optimized further by considering the dietary habits of Chinese population. Region-specific dietary guidelines should also be formulated for residents of different regions based on their common and specific problems of food and nutrient intake. Chinese population should generally increase their consumption of whole grains, fruits, and soy products and reduce their consumption of ultra-processed foods, refined grains and red meat. At the same time, the problem of micronutrient deficiencies in different regions can be improved in three ways: increase in the amount of nutrient-rich food, fortification of food nutrients, and supplementation of nutrients.

Second, optimizing dietary patterns from the demand side is also an important measure to facilitate the transformation of sustainable agrifood systems. With the goal of sustainable and healthy diets, the structure of food production needs to be adjusted: there should be a transition to green and low-carbon production methods. It is also urgent to cooperate with multiple departments to develop a regional guidance plan on "sustainable and healthy diets for residents" to guide the transformation of residents' food consumption.

Third, it is important to guide investment and trade toward a nutrition-oriented food supply. Both domestic and overseas markets and resources should be used to promote China's transition to a sustainable and healthy dietary model, which are Combined with foreign direct investment access policies and the inclusion of dietary nutrition improvement targets in World Trade Organization negotiations.

Fourth, highly targeted dietary intervention programs should be designed and implemented to guide concerted efforts of multiple parties to promote the transformation of sustainable and healthy diets for all. A national nutrition improvement plan can be implemented to strengthen nutrition education and guidance, pay attention to different groups of people and various consumption scenarios, and design targeted strategies for dietary intervention. Food education should be introduced to guide citizens toward nurturing good dietary habits and taking direct responsibility for their own health. Furthermore, a favorable market environment should be created to motivate consumers to choose sustainable and healthy diets, while policies, regulations, and financial support can encourage enterprises, institutions, and communities to build central kitchens to improve diets.



Shenggen Fan

Academy of Global Food Economics and Policy,
College of Economics and Management,
China Agricultural University

Wei Si

Academy of Global Food Economics and Policy,
College of Economics and Management,
China Agricultural University

Kevin Z. Chen

China Academy for Rural Development,
Zhejiang University
International Food Policy Research Institute

Ting Meng

Academy of Global Food Economics and Policy,
College of Economics and Management,
China Agricultural University





Chapter 1

Strategic Direction of Chinese Sustainable Healthy Diets in an International Context

Jiayu Xia^{1,2}, Shenggen Fan^{1,2}, Kevin Z. Chen^{3,4},
Yumei Zhang^{1,2}, Xiaolong Feng^{1,2}, Ting Meng^{1,2}

1. Academy of Global Food Economics and Policy, China Agricultural University

2. College of Economics and Management, China Agricultural University

3. China Academy of Rural Development, Zhejiang University

4. International Food Policy Research Institute



Figure 1 EAT-Lancet(Planetary Healthy) Diet

Source: EAT-Lancet Commission, 2019([source:https://eatforum.org/eatlancet-commission/eat-lancet-commission-summary-report/](https://eatforum.org/eatlancet-commission/eat-lancet-commission-summary-report/))

1.1 Introduction

Malnutrition and environmental degradation are two major challenges facing the world today that demand urgent attention. In 2021, almost a third (29.3 percent) of the world's population, or 2.3 billion people, experienced moderate or severe food insecurity (FAO et al. 2022). At the same time, approximately 40 percent of adults and 20 percent of children were overweight or obese (WHO 2021). Poor diets are the leading cause of malnutrition, but food production and consumption patterns are also taking a significant toll on the environment. In fact, food systems contribute to one-third of global greenhouse gas (GHG) emissions, with agricultural production accounting for 39 percent of these emissions (IPCC 2019; Crippa et al. 2021; UN 2022). Anthropogenic impacts account for 35 percent of the degradation of agricultural land, and agriculture is a major source of water pollution in many countries (FAO 2021).

In recent years, global focus on the synergistic

effects of diets on both health and the environment has increased (Springmann et al. 2018; Willett et al. 2019; Zhang and Chai 2022). Healthy diets are more environmentally sustainable, while sustainable diets can bring significant health benefits (Behrens et al. 2017; Sánchez et al. 2020; Guasch-Ferr et al. 2021; Macdiarmid et al. 2012; He et al. 2021). By moving toward sustainable healthy diets, a win-win outcome can be achieved for both nutritional health and environmental sustainability (Springmann et al. 2020; Academy of Global Food Economics and Policy 2021; Sheng et al. 2021).

Therefore, the promotion of sustainable healthy diets and the transformation of demand-side agrifood systems are important and urgent for the world and for China, which is currently facing severe challenges of nutrient imbalance and environmental degradation. This chapter builds on the main findings of chapters 2-5 of the report, aims to summarize the health and environmental impacts of diets, reviews the progress of global research



Figure 2 The Chinese Food Guide Pagoda (2022)

Source: Chinese Nutrition Society, 2022(source: <http://dg.cnsoc.org/>)

on sustainable healthy diets, analyzes the current state of diets in China and the major issues facing the transformation of sustainable healthy diets, and proposes policy recommendations for China. This will serve as a benchmark for Chinese nutritional health decision making and environmental sustainability policies as well as a reference for the transformation of sustainable and healthy diets in other countries.

1.2 Health and Environmental Impacts of Diets

Currently traditional and influential healthy diets worldwide include the Mediterranean diet, the Nordic diet, the traditional Japanese diet, and the Jiangnan diet. These diets are followed by a certain number of individuals and are recognized as healthy diets. At the same time, to improve population's health, more than 100 countries have formulated food source dietary guidelines or proposed specific dietary patterns, such

as the Dietary Approaches to Stop Hypertension (DASH) diet, to prevent and control the occurrence of diseases caused by poor diets. Both naturally occurring and recommended healthy diets demonstrate commonalities of more vegetables, fruits, fish, and poultry and less red meat. They emphasize whole grain intake in cereals, less oil and salt, a variety of ingredients, simple cooking, and less processing (Fischer and Garnett 2016; Herforth et al. 2019).

This chapter focuses on health impact as well as environmental impact of diets. This is because currently available healthy diets and dietary guidelines, although primarily from a nutritional health perspective, have been shown to be somewhat sustainable by a large body of research. Additionally, the only currently quantified sustainable healthy diet is the EAT-Lancet diet. Furthermore, health and environmental impact is primarily estimated by different modeling approaches.



1.2.1 Healthy Impact of Diets

There is sufficient evidence from population-based studies to suggest that diets high in fruits, vegetables, whole grains, legumes, nuts, fish or seafood, and unsaturated vegetable oils are associated with reduced risk of cardiovascular disease and all-cause mortality. However, red meat and processed meat are associated with an increased risk of cardiovascular disease and all-cause mortality (He et al. 2019; Willett et al. 2019; Chinese Society of Nutrition 2021).

Replacing 25 to 100 percent of animal foods with healthy plant-based foods for the same energy intake would result in a corresponding 4 to 12 percent reduction in global premature mortality in 2030, compared to the 2010 reference standard. The reduction in high-income countries would be the most significant (Springmann et al. 2018). The global shift from the current diet to the EAT-Lancet diet could prevent approximately 11 million deaths annually, accounting for 19 to 24 percent of all adult deaths (Willett et al. 2019). Studies show that people who follow a sustainable healthy diet are at a lower risk of diet-related diseases and live longer. A sustainable healthy diet has the potential to provide significant health benefits in three main ways.

It helps reduce the risk of being overweight and obesity. Obesity is a major global public health issue. An association between elevated body mass index and a broad spectrum of chronic conditions has been established (Boutari et al. 2022). The mortality reduction effect of adopting a healthy diet is largely (63 to 94 percent) because of a reduction in weight-related risk factors (Zagmutt et al. 2020). Those who follow a healthy diet, such as the Jiangnan diet (Chinese Nutrition Society 2021), the Mediterranean diet (Buckland et al. 2008; Bendall et al. 2018), the traditional Japanese diet (Hatta et al. 2022; Imai et al. 2019), and the Nordic diet (Iriti et al. 2020), are less likely to be overweight or obese.

It helps reduce the risk of developing chronic diseases, such as cardiovascular disease, type 2 diabetes, and cancer. Healthy diets contribute to the reduction of diet-related, preventable, and noncommunicable disease risk factors (Iriti et al. 2020). The Mediterranean diet has

been shown to reduce the risk of hypertension; following a Mediterranean diet increases life expectancy by reducing hypertension (Gao et al. 2018), diabetes, and cardiovascular disease mortality (Tilman and Clark 2014; Guasch-Ferr et al. 2021). Dietary Guidelines for Chinese population established a significant positive correlation among overall health of the population (Zang et al. 2018); higher dietary index scores; and lower mortality from cardiovascular disease, cancer, and diabetes (Yu et al. 2014; Chen et al. 2018). Nordic diets can help combat diabetes in the general population (Massara et al. 2022) and reduce myocardial infarction and stroke in men (Galbete et al. 2018; Hansen et al. 2017).

It helps reduce the likelihood of cognitive impairment such as Alzheimer's disease. Adherence to the Mediterranean diet, more DASH, and reduced cognitive decline were associated with a lower risk of Alzheimer's disease (Mohamed et al. 2010; Brink et al. 2019; Guasch-Ferr et al. 2021). The MIND diet, a combination of the Mediterranean and DASH diets, improves cognitive health in older adults (Marcason et al. 2015), including preventing cognitive decline and improving cognitive performance (Van De Rest et al. 2015; Chen et al. 2019; Wengreen et al. 2013), and minimizes the risk of Alzheimer's disease by 53 percent. It also significantly slows decline in cognitive functions such as situational, semantic, and working memory and sensory speed (Morris et al. 2015).

1.2.2 Environmental Impact of Diets

The environmental impact of different types of food vary significantly from farm to fork, through production, processing, transport, storage, and cooking (Poore and Nemecek 2018). Animal foods, particularly ruminant meats such as beef and lamb, have significantly higher environmental impacts than plant-based foods (Kanyama et al. 2009; Godfray et al. 2018; FAO and WHO 2019). Therefore, a sustainable diet that is low carbon and environment friendly involves consuming more plant-based foods and fewer ruminant animal foods. Sustainable, healthy diets can effectively reduce dietary-related environmental impacts in three main ways (Aleksandrowicz et al. 2016; Behrens et al. 2017; He et al. 2021).

Diet is a primary source of GHG emissions (Theurl



et al. 2020), and an optimized diet can significantly reduce emissions. Globally, the adoption of sustainable healthy diets could reduce the social costs of diet-related emissions by 41 to 47 percent by 2030 (FAO et al. 2020). Transitioning to diets consistent with standard dietary guidelines would reduce emissions from the food system by 29 to 70 percent by 2050 (Springmann et al. 2020). A plant-rich diet could reduce emissions from food consumption by 41 percent by 2060; replacing some traditional meat with shellfish could effectively reduce emissions from the food system (Zhang M et al. 2022).

Changes in population dietary patterns have resulted in changes in water and land-use requirements (He et al. 2019), with dietary changes contributing more to the increase in total food system water footprint (WF) than population growth (Wang et al. 2022). Reductions in food waste and the area of agricultural land associated with reduced dietary meat consumption provide the greatest buffer against loss of land (Fitton et al. 2019). The adoption of sustainable diets can reduce land use by 70 to 80 percent and water use by 50 percent, which is proportional to reductions in animal feed (Aleksandrewicz et al. 2016). In Europe, substituting new foods or plant-based foods for animal protein can reduce land and water use related to the diet by more than 80 percent while meeting nutrient requirements and consumption budgets (Mazac et al. 2022).

Nitrogen and phosphorus emissions have exceeded the boundaries of what the planet can sustain; the increasing imbalance of nitrogen and phosphorus not only affects natural ecosystems but also poses a severe threat to food production and food security (Peñuelas and Josep 2022). The shift to a healthy, balanced diet is effective in reducing the consumption of phosphorus and the resource emissions of nitrogen and phosphorus to water bodies (Thaler et al. 2015). Fish and livestock products account for the majority of foodborne nitrogen emissions, which account for approximately half of total food intake (Xing et al. 2021). Minimizing livestock production is thought to be the most effective means of reducing environmental problems related to nitrogen and phosphorus (Steffen et al. 2015). Halving the European Union's consumption of meat, dairy, and eggs would result in a 40 percent reduction in its nitrogen emissions (Westhoek et al. 2015).

1.3 Global Sustainable Healthy Diets

More than 100 countries have developed food dietary guidelines, all of which provide appropriate guidance to improve the health of their populations (FAO 2023). However, the majority of these guidelines do not cover the unavoidable environmental impact of diets. This issue has been raised in recent years (Herforth et al. 2019; Springmann et al. 2020; Martini et al. 2021).

In 2010, the Food and Agriculture Organization of the United Nations (FAO) introduced the concept and definition of “sustainable diets”—diets with low environmental impact that contribute to food and nutrition security and healthy lives for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe, and healthy (FAO 2010). They optimize natural and human resources (FAO 2010). The introduction of this definition demonstrates the need to introduce environmental factors into prevailing dietary guidelines and to move food systems in a more sustainable direction.

In 2019, the development of the EAT-Lancet diet was first presented and studied in *The Lancet*, quantifying dietary structures that contribute to human health and environmental sustainability. On the EAT-Lancet plate, vegetables and fruit constitute the bulk of diet; the other half consists mainly of whole grains, plant protein, unsaturated vegetable oils, and (optional) moderate amounts of animal protein. Essentially, it is a “flexible vegetarian” or meat-free diet. The Lancet also states that global consumption of fruits, vegetables, nuts, and beans must double by 2050 and that consumption of foods such as red meat and sugar must be reduced by more than 50 percent (Willett et al. 2019). The EAT-Lancet diet provides a concrete guide to sustainable healthy diets and is an important indicator of where dietary change is headed worldwide.

However, significant gaps exist in current food consumption, national dietary guidelines, and the EAT-Lancet diet. Additionally, significant differences in resource endowments and dietary cultures worldwide will pose challenges to implementation at the national or regional levels. Blackstone and Conrad (2020) compared



the EAT-Lancet diet to the three recommended diets in the US Dietary Guidelines, the Healthy American Diet, the Healthy Mediterranean Diet, and the Healthy Vegetarian Diet. They found differences in the amount of whole grains, fruits, starchy vegetables, red meat, nuts, and discretionary calories. The EAT-Lancet diet contains 45 to 56 percent less fruit, 60 percent less starchy vegetables, and 80 percent less red meat than the diet specified in the US Dietary Guidelines (except when compared to the Healthy Vegetarian Diet). In addition, some dietary components of the EAT-Lancet diet are difficult to obtain. For example, the EAT-Lancet diet recommends a daily intake of 50 grams of nuts, but according to the Global Burden of Disease Study, the optimal intake is 21 grams per day, and the current global per capita consumption of nuts and seeds is only 3 grams per day (Afshin et al. 2019).

In 2019, the FAO and World Health Organization agreed on the definition of the term “sustainable healthy diets,” defining them as “dietary patterns that promote all dimensions of individuals’ health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable.” Furthermore, they established guidelines for sustainable healthy diets while agreeing on the objectives of sustainable healthy diets: to achieve optimal growth and development of all individuals and support physical, mental, and social well-being at all life stages for present and future generations; contribute to preventing all forms of malnutrition (i.e., undernutrition, micronutrient deficiency, overweight, and obesity); reduce the risk of diet-related noncommunicable diseases; and support the preservation of biodiversity and planetary health. Additionally, they state that countries should make trade-offs according to their national circumstances and goals to achieve food system transformation, providing sustainable healthy diets and contributing to the achievement of sustainable development goals at the national level (FAO and WHO 2019).

The global consensus on the importance and urgency of moving toward sustainable and healthy diets is prominent, the 2021 State of Food Security and Nutrition in the World Report recommends that by 2030, all countries would need to move toward sustainable healthy diets to minimize the costs to health and climate change (FAO et al. 2021). However, existing

studies are mostly theoretical in their assessments and prediction, lack focus at practical levels, and are often based on analysis of global averages rather than locally applicable data. The conclusions drawn from studies are simplistic and ignore the differences between countries and regions of the world, making the findings biased and unrealistic (Poore and Nemecek 2018). The focus on the assessment of sustainable healthy diets is partial and lacks systematic and comprehensive indicator construction (Harrison et al. 2021). In the future, developing sustainable healthy diets must take into account different resource endowments, dietary habits and economic levels. It also needs to balance adaptation to different regions and populations as well as acceptability and accessibility. Furthermore, they need to be supported by concrete scientific evidence.

1.4 Sustainable Healthy Diets in China

1.4.1 Current Situation of the Chinese Population's Diets

With the increase in agricultural productivity and income levels, China has made significant strides in reducing hunger and malnutrition. There has been notable progress in the quality and composition of the population's diet. The consumption of nutritious foods, such as fruits, eggs, aquatic products, and dairy products, has increased gradually (Academy of Global Food Economics and Policy 2021). There is also a steady rise in consumption of animal-based foods such as red meat and chicken as well as a significant increase in the consumption of refined cereals and edible oils, indicating a transition from the traditional Chinese plant-based dietary pattern to a Western dietary pattern (Zhao et al. 2018). This change may be the result of changes in sociodemographic factors and consumer characteristics, and trade and investment have been shown to influence dietary change (Kearney 2010). Currently, the diet of Chinese individuals is characterized by an imbalanced eating pattern with excessive cereal and meat consumption and insufficient intake of vegetables, fruits, and dairy products (Academy of Global Food Economics and Policy 2022), which presents new challenges for nutritional health and the natural resource environment.

Diet-related nutrition and health issues are



becoming increasingly important. The coexistence of over- and undernutrition among Chinese residents continues to highlight the problem of overweight and obesity and increased incidence of major chronic diet-related diseases continues to increase (He et al. 2019), thereby giving rise to nutritional health issues and challenges (National Health and Wellness Commission and Bureau of Disease Prevention and Control 2020; Ministry of Agriculture and Rural Affairs and Institute of Food and Nutrition Development 2022). First, the population of overweight and obese individuals is increasing rapidly across all age groups in both urban and rural areas; obesity has emerged as a significant public health issue in China (Pan et al. 2021). The rate of overweight and obesity in the Chinese population age 18 years and older is 50.7 percent in 2020, with 34.3 percent of this population overweight and 16.4 percent obese. Obesity in adults is increasing at a faster rate than overweight, and increased rates of overweight and obesity in rural population are higher than in urban population. The rates of overweight and obesity in the adult male population in 2018 were 37.6 percent and 16.1 percent, respectively (Chinese Nutrition Society 2021). Second, chronic disease is significant problem. Malnutrition is the leading cause of illnesses and death in Chinese residents (He et al. 2019; Afshin et al. 2019); chronic noncommunicable diseases like cardiovascular disease, cancer, chronic respiratory disease, and diabetes account for 88 percent of all deaths in China (National Health and Wellness Commission 2019). The prevalence of diabetes in adults is increasing year by year, touching 11.9 percent in 2020, which almost doubles the prevalence in 2002 and four times higher than in 1989. The prevalence of hypertension is also increasing, with almost a third of the population already suffering from hypertension in 2020. There has been an increase of approximately 10 percentage points compared to 2002 (Chinese Nutrition Society 2021). Third, the problem of hidden hunger remains. Many individuals in China, particularly key populations such as children and pregnant women, continue to face significant micronutrient deficiencies. As of 2018, up to 21.2 percent of children age 6 years and younger have anemia. The prevalence of vitamin A marginal deficiency in children aged 6-17 years is 14.7 percent, and zinc deficiency in children under 14 years of age is as high as 27 percent

(National Health and Wellness Commission Bureau of Disease Prevention and Control 2020; Cai et al. 2021).

At the same time, changes in the dietary structure of the Chinese population have also exacerbated environmental issues. China is the world's second most populous country, and its demand for meat and cereals increased by 19 percent and 10 percent of global food, respectively, between 2010 and 2020 (OECD and FAO 2021). FAO statistics show that carbon emissions from China's agricultural food system increased from 1,177 million metric tons in 1990 to 1,864 million metric tons in 2020, an increase of 58 percent. Methane and nitrous oxide emissions from agricultural production activities are responsible for more than 40 percent and 50 percent of the national emissions of methane and nitrous oxide, respectively (Ministry of Ecology and Environment 2018). China's agricultural food system is experiencing an increase in emissions, water consumption, and land use area of approximately 1.1 percent, 1.8 percent, and 2.0 percent per year, respectively, with the growth in meat consumption being the largest contributor to these three environmental pressures (He et al. 2018). In particular, enteric fermentation of livestock and management of animal manure are important sources of agricultural emissions. The change of food structure places increasing demands on agricultural lands given that consumption of animal products is gradually increasing as the proportion of total land demand for food production per capita (Zhao et al. 2014), and that the WF of food consumption is increasing (Liu et al. 2008). A disproportionate share of food consumption for meat (highest WF) and a small share of consumption for vegetables (lowest WF) is the primary reason for the large WF per unit of food consumption (Xu et al. 2021).

1.4.2 Challenges to the Transformation of Sustainable Healthy Diets in China

With increasing nutrient imbalances and environmental degradation, there is a pressing need to transform the diets of China's people. Studies conducted in recent years have demonstrated the potential for a transition to sustainable and healthy diets for China's population that can improve their nutritional health and optimize the use of resources. By 2030, it is expected that the prevalence of chronic diet-related diseases will be significantly



reduced, resulting in a reduction of 1,802,000 premature deaths and 665,000 deaths, which represents a 19.2 percent and 19.5 percent reduction, respectively, compared to the 2010 reference standard (Springmann et al. 2020). Furthermore, this shift to sustainable diets can lead to a 19 percent, 15 percent, and 30 percent reduction in carbon, water, and ecological footprints, respectively, and decrease emissions by 146 million to 202 million metric tons (Sheng et al. 2021; Yin et al. 2021). Nevertheless, the following four challenges remain to be addressed to further the transition to a sustainable and healthy diet for China's population.

There is inadequate research on healthy diets in China. First, Dietary Guidelines for Chinese Residents, which is based on Western dietary guidelines, does not have Chinese features; some parts are difficult for Chinese residents to achieve in their daily diets. Second, current national dietary guidelines do not consider the major differences in resource endowments and dietary patterns of different regions, and analyses based on national-average data cannot provide specific insights into the diverse daily diets of local residents and the precise transformation that they merit. Third, the pervasive problems of overweight, obesity, and hidden hunger have not been adequately addressed, and no specific guidance programs have been developed to ameliorate them.

Dietary Guidelines for Chinese Residents does not consider the sustainability of resources and the environment. The current trend of shifting the dietary structure of the population toward animal-based foods will result in greater pressure on resources and the environment in the agricultural food system. Even if we follow the recommended diets in Dietary Guidelines for Chinese Residents (2022), a gap will remain. There is much room for optimizing sustainable healthy diets in China, but there is a lack of clear direction for optimization, and the gap between actual supply and recommended consumption should not be ignored.

International trade and foreign investment have been neglected in their impact on the sustainable healthy diets of the population. International trade and foreign investment have become increasingly important in transforming diets of residents in China. International trade has altered the structure and quality of diets of Chinese people, as their food preferences gradually shift

toward animal-source foods. Foreign direct investment, represented by Western-style fast food, has increased the consumption of unhealthy foods by residents of China, affecting their nutritional health while simultaneously constraining the sustainability of resources and the environment. However, China has never used international trade and foreign investment as a grip to change the diets of its population.

A specific and effective intervention system to guide the population's dietary intake is lacking. Interventions on the consumption side are the key to achieving a sustainable and healthy diet for the population and are a powerful traction for the transformation of the agrifood system. Residents' consumption behavior is influenced by a variety of factors and interventions: information intervention, behavioral intervention, and economic incentives can effectively contribute to the transformation of diets. Although China's nutrition support policies have been effective in improving the nutrition of specific groups of people, the existing nutrition support policies have not considered the shift toward sustainable healthy diets and lack targeted interventions for key groups and scenarios.

1.5 Strategic Direction for Advancing the Transformation of Sustainable Healthy Diets in China

During the past decade, an increasing number of countries have begun to integrate health and sustainability into both national food policies and consumer education programs as a primary response to nutritional imbalances and environmental sustainability. This will contribute to the transformation of agrifood systems for human health and planetary sustainability by influencing national nutrition programs, trade and investment patterns, consumer food choices, and agricultural production. However, in-depth research on the precise dietary shifts in different countries or regions is needed to propose concrete and feasible guidelines. In light of the many challenges facing China's sustainable healthy dietary transition, how should China actively respond? Based on the international context of sustainable healthy diets and the findings of the study on sustainable healthy diets in China presented in chapters 2 to 5 of the report, this chapter proposes four major



strategies to promote the transformation of sustainable healthy diets in China.

Establish a healthy dietary pattern that is appropriate for Chinese population. While appropriately preserving and advocating Chinese characteristics such as more plant-based foods in traditional diets, China should also provide regional guidelines on healthy diets that are easy to operate and unique to the resource endowments and dietary habits of different regions. To address the common problems of diets in different regions, increasing the consumption of whole grains, fruits, and soya products and reducing the consumption of ultra-processed foods, refined grains and red meat through increasing supply and food substitution should be encouraged. The common problem of hidden hunger should be addressed by providing a variety of alternative food options.

Propose a sustainable healthy diets optimization program. Based on the premise of satisfying the nutritional health of the population, the environmental impact of food consumption should be considered, and the dietary structure of the population should be further optimized. Taking into full consideration the resources and environmental endowments of different regions and the characteristics of agricultural production, a cross-sectoral coordination mechanism should be established to jointly formulate national and regional guidance programs on “sustainable healthy diets for the population” to guide the transformation of the population’s food consumption toward sustainability and health. The program should involve adjustments to the structure of the food supply, with increased research and production support for legumes, fruits, etc.. The “Big Food Concept” should be implemented to improve the supply of diverse foods to meet the population’s needs for sustainable healthy diets. Additionally, all segments of the agrifood system should be transformed into a green and low-carbon system.

Adjust international trade and overseas investment to improve the diet of the population. Taking advantage of the development trend of economic globalization, China should incorporate dietary improvement into its policy objectives for international trade and overseas investment, optimize trade policies, and adjust overseas investment tactics to achieve the dual objectives of population health and environmental sustainability. In

terms of trade, the goal of improving dietary nutrition should be included in trade negotiations, making full use of domestic and international markets resources to ensure China’s food security level. In terms of investment, investment access restrictions in the food sector should be liberalized, directing investment toward industries related to sustainable healthy diets. This can be achieved by promoting the implementation of a detailed investment review system and regulatory regime in this area. In the future, nutrition, health and sustainable development must be included in the agenda of agricultural negotiations in WTO negotiations.

Take several measures to guide interventions to change the diet of the population toward sustainable health. Food education for all people should be provided; and families, schools, and communities (villages) should serve as entry points for food education for all individuals. This will help establish a sustainable healthy diet and encourage individuals to take responsibility for their own health. Policies and regulations can work together to establish a supportive market and consumer environment that guides and motivates consumers to change their diets toward sustainable health. Precise interventions for different populations, regions, and consumption scenarios can also be implemented to promote sustainable and healthy diets.

References

- Academy of Global Food Economics and Policy (AGFEP), China Agricultural University, China Academy of Rural Development (CARD), Zhejiang University, Center for International Food and Agricultural Economics (CIFAIE), Nanjing Agricultural University, Institute of Agricultural Economics and Development (IAED), Chinese Academy of Agricultural Sciences and International Food Policy Research Institute (IFPRI). China and Global Food Policy Report [R]. Beijing: Institute for Global Food Economics and Policy Research, 2021.
- Academy of Global Food Economics and Policy (AGFEP), China Agricultural University, China Academy of Rural Development (CARD), Zhejiang University, Center for International Food and Agricultural Economics (CIFAIE), Nanjing Agricultural University, Institute of Agricultural Economics and Development (IAED), Chinese Academy of Agricultural Sciences and International Food Policy Research Institute (IFPRI). China



- and Global Food Policy Report [R]. Beijing: Institute for Global Food Economics and Policy Research, 2022.
- Afshin A, Sur PJ, Fay KA et al. (2019) Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study [R]. *The Lancet*, 2017, 393:P1958-72.
- Ahmed S, Downs S and Fanzo J (2019) Advancing an Integrative Framework to Evaluate Sustainability in National Dietary Guidelines. *Front. Sustain. Food Syst.* 3:76. doi: 10.3389/fsufs.2019.00076
- Aleksandrowicz L, Green R, Joy E J M, et al., 2016. The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review[J]. *Plos One*, 11(11): e0165797. <https://doi.org/10.1371/journal.pone.0165797>.
- Behrens P, Kieft-De Jong J C, Bosker T, et al. Evaluating the environmental impacts of dietary recommendations[J]. *Proceedings of the National Academy of Sciences*, 2017, 114(51): 13412-13417. DOI:10.1073/pnas.1711889114.
- Bendall C L, Mayr H L, Opie R S, et al., 2018. Central obesity and the Mediterranean diet: A systematic review of intervention trials[J]. *Critical Reviews in Food Science and Nutrition*, 58(18): 3070-3084. <https://doi.org/10.1080/10408398.2017.1351917>.
- Blackstone NT & Conrad Z. Comparing the recommended eating patterns of the EAT-lancet commission and dietary guidelines for Americans: implications for sustainable nutrition[J]. *Current Developments in Nutrition*, 2020, 4: nzaa015.
- Boutari C, Mantzoros C S. 2022. A 2022 update on the epidemiology of obesity and a call to action: as its twin COVID-19 pandemic appears to be receding, the obesity and dysmetabolism pandemic continues to rage on[J]. *Metabolism*, 133: 155217. <https://doi.org/10.1016/j.metabol.2022.155217>.
- Buckland G, Bach A, Serra-Majem L. 2008. Obesity and the Mediterranean diet: a systematic review of observational and intervention studies[J]. *Obesity Reviews*, 9(6): 582-593. <https://doi.org/10.1111/j.1467-789X.2008.00503.x>.
- Bureau of Disease Prevention and Control, National Health Commission. China's population nutrition and chronic diseases report 2020 [R]. Beijing: Bureau of Disease Prevention and Control of the National Health and Health Commission, 2020.
- Cai-Jin Y, Jing-Ying S, Gang-Xi L. Meta-analysis of zinc deficiency and its influence factors in children under 14-year-old in China [J] *J Fam Med*, 2021, 8(5):1257.
- Carlos Gonzalez Fischer & Tara Garnett. Plates, pyramids, planet. Developments in national healthy and sustainable dietary guidelines: a state of play assessment[R], FAO and the University of Oxford, 2016.
- Carlsson-Kanyama A, González A D. Potential contributions of food consumption patterns to climate change[J]. *The American Journal of Clinical Nutrition*, 2009, 89(5): 1704S-1709S. DOI:10.3945/ajcn.2009.26736AA.
- Chen X, Maguire B, Brodaty H, et al., 2019. Dietary patterns and cognitive health in older adults: a systematic review[J]. *Journal of Alzheimer's Disease*, 67(2): 583-619.
- Chen, PY., Fang, AP., et al., 2018. Adherence to the Chinese or American Dietary Guidelines is Associated with A Lower Risk of Primary Liver Cancer in China: A Case-control Study[J]. *Nutrients*, 10(8), 1113.
- China Nutrition Society. Dietary Guidelines for Chinese Residents 2022 [M]. Beijing: Chinese Society of Nutrition, 2022.
- Chinese Nutrition Society. Research Report of the Academy of Sciences on Dietary Guidelines for Chinese Residents [R]. Beijing: Chinese Society of Nutrition, 2021.
- Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N. and Leip, A. (2021). Food systems are responsible for a third of global anthropogenic emissions. *Nature Food* 2(3), 198-209. <https://doi.org/10.1038/s43016-021-00225-9>.
- Dowler E, Caraher M, Lincoln P, eds. Inequalities in Food and Nutrition: Challenging Lifestyles. In: *Challenging Health Inequalities: from Acheson to Choosing Health*[R]. Bristol, United Kingdom: The Policy Press, 2007.
- FAO and WHO. 2019. Sustainable healthy diets - Guiding principles[R]. Rome.
- FAO, Food-based dietary guidelines, <https://www.fao.org/nutrition/education/food-dietary-guidelines/background/zh/>, 2023.
- FAO, IFAD, UNICEF, WFP and WHO. 2020. The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets. FAO. Available online at <https://doi.org/10.4060/ca9692en>.
- FAO, IFAD, UNICEF, WFP and WHO. 2021. The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all. FAO. Available online at <https://www.fao.org/publications/sofi/2021/en>.
- Fischer, C. G., and Garnett, T. (2016). Food and Agriculture Organization of the United Nations, University of Oxford and Food Climate Research Network. Plates, Pyramids, and Planets: Developments in National Healthy and Sustainable Dietary Guidelines: A State of Play Assessment (Oxford).



- Fitton N, Alexander P, Arnell N, et al., 2019. The vulnerabilities of agricultural land and food production to future water scarcity[J]. *Global Environmental Change-Human and Policy Dimensions*, 58: 101944. <https://doi.org/10.1016/j.gloenvcha.2019.101944>.
- Galbete C, Kroeger J, Jannasch F, et al., 2018. Nordic diet, Mediterranean diet, and the risk of chronic diseases: the EPIC-Potsdam study[J]. *Bmc Medicine*, 16: 99. <https://doi.org/10.1186/s12916-018-1082-y>.
- Global Nutrition Report. 2022: Stronger commitments for greater action [R]. Available at: <https://globalnutritionreport.org/reports/2022-global-nutrition-report/>
- Godfray H C J, Aveyard P, Garnett T, et al., 2018. Meat consumption, health, and the environment[J]. *Science*, 361(6399): eaam5324. <https://doi.org/10.1126/science.aam5324>.
- Hansen C P, Overvad K, Kyro C, et al., 2017. Adherence to a Healthy Nordic Diet and Risk of Stroke: A Danish Cohort Study[J]. *Stroke*, 48(2): 259-264. <https://doi.org/10.1161/STROKEAHA.116.015019>.
- Harrison MR, Palma G, Buendia TBueno-Tarodo M, Quell D and Hachem F(2022) A Scoping Review of indicators for Sustainable Healthy Diets. *Front. Sustain. Food Syst* 5:822263doi: 10.3389/fsufs.2021.822263
- Hatta M, Horikawa C, Takeda Y, et al., 2022. Association between Obesity and Intake of Different Food Groups among Japanese with Type 2 Diabetes Mellitus-Japan Diabetes Clinical Data Management Study (JDDM68)[J]. *Nutrients*, 14(15): 3034. <https://doi.org/10.3390/nu14153034>.
- He G, Zhao Y, Wang L, et al., 2019. China's food security challenge: Effects of food habit changes on requirements for arable land and water[J]. *Journal of Cleaner Production*, 229: 739-750. <https://doi.org/10.1016/j.jclepro.2019.05.053>.
- He P, Baiocchi G, Feng K, et al. Environmental impacts of dietary quality improvement in China[J]. *Journal of Environmental Management*, 2019, 240: 518-526. DOI:10.1016/j.jenvman.2019.03.106.
- He P, Feng K, Baiocchi G, et al. Shifts towards healthy diets in the us can reduce environmental impacts but would be unaffordable for poorer minorities[J]. *Nature Food*, 2021, 2(9): 664-672. DOI:10.1038/s43016-021-00350-5.
- He Y, Li Y, Yang X, et al., 2019. The dietary transition and its association with cardiometabolic mortality among Chinese adults, 1982-2012: a cross-sectional population-based study[J]. *Lancet Diabetes & Endocrinology*, 7(7): 540-548. [https://doi.org/10.1016/S2213-8587\(19\)30152-4](https://doi.org/10.1016/S2213-8587(19)30152-4).
- He Y, Zhao W, Zhang J, et al., 2019. Data Resource Profile: China National Nutrition Surveys[J]. *International Journal of Epidemiology*, 48(2): 368-368f. DOI:10.1093/ije/dyy289.
- Herforth, A., Bai, Y., et al.. Cost and Affordability of Healthy Diets Across and Within Countries. FAO Agricultural Development Economics Technical Study. 2020
- Imai T, Miyamoto K, Sezaki A, et al., 2019. Traditional Japanese Diet Score - Association with Obesity, Incidence of Ischemic Heart Disease, and Healthy Life Expectancy in a Global Comparative Study[J]. *Journal of Nutrition Health & Aging*, 23(8): 717-724. <https://doi.org/10.1007/s12603-019-1219-5>.
- Institute of Food and Nutrition Development, Ministry of Agriculture and Rural Affairs. China food and nutrition development report 2020 [R]. Beijing: Institute of Food and Nutrition Development, Ministry of Agriculture and Rural Affairs, 2022.
- Intergovernmental Panel on Climate Change (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva. <https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/>.
- Iriti M, Varoni E M, Vitalini S. 2020. Healthy Diets and Modifiable Risk Factors for Non-Communicable Diseases-The European Perspective[J]. *Foods*, 9(7): 940. <https://doi.org/10.3390/foods9070940>.
- Kearney J, 2010. Food consumption trends and drivers[J]. *Philosophical Transactions of the Royal Society B-Biological Sciences*, 365(1554): 2793-2807. DOI:10.1098/rstb.2010.0149.
- Liu J, Savenije H H G. 2008. Food consumption patterns and their effect on water requirement in China[J]. *Hydrology and Earth System Sciences*, 12(3): 887-898. <https://doi.org/10.5194/hess-12-887-2008>.
- Macdiarmid J I, Kyle J, Horgan G W, et al., Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? [J]. *The American journal of Clinical Nutrition*, 2012, 96(3): 632-639.DOI:10.3945/ajcn.112.038729.
- Marcason W.2015.What are the components to the MIND diet? [J]. *Journal of the Academy of Nutrition and Dietetics*, 115(10): 1744-1744.
- Marco Springmann, Luke Spajic, Michael A Clark, Joseph Poore, Anna Herforth, Patrick Webb, Mike Rayner, Peter Scarborough. The healthiness and sustainability of national and global food based dietary guidelines: modelling study *BMJ*2020;370:m2322http://dx.doi.org/10.1136/bmj.m2322
- Martini, D.; Tucci, M.; Bradfield, J.; Di Giorgio, A.; Marino, M.; Del Bo', C.; Porrini, M.; Riso, P. Principles of Sustainable Healthy Diets in Worldwide Dietary Guidelines: Efforts So Far and Future Perspectives. *Nutrients* 2021, 13, 1827.<https://doi.org/10.3390/nu13061827>.



- Massara P, Zurbau A, Glenn A J, et al., 2022. Nordic dietary patterns and cardiometabolic outcomes: a systematic review and meta-analysis of prospective cohort studies and randomised controlled trials[J]. *Diabetologia*, 65(12): 2011-2031. <https://doi.org/10.1007/s00125-022-05760-z>.
- Mazac R, Meinila J, Korkalo L, et al., 2022. Incorporation of novel foods in European diets can reduce global warming potential, water use and land use by over 80%[J]. *Nature Food*, 3(4): 286-+. <https://doi.org/10.1038/s43016-022-00489-9>.
- Mertens E, van't Veer P, Hiddink GJ et al. Operationalising the health aspects of sustainable diets: a review[J]. *Public Health Nutrition*, 2017, 20: 739-57.
- Ministry of Ecology and Environment. China Climate Change Second Biennial Update Report 2018 [R]. Beijing: Ministry of Ecology and Environment, 2018.
- Mohamed H E, El-Swefy S E, Rashed L A, et al., 2010. Obesity and neurodegeneration: effect of a Mediterranean dietary pattern[J]. *Nutritional Neuroscience*, 13(5): 205-212. <https://doi.org/10.1179/147683010X12611460764444>.
- Morris M C, Tangney C C, Wang Y, et al. 2015. MIND diet associated with reduced incidence of Alzheimer's disease[J]. *Alzheimers & Dementia*, 11(9): 1007-1014.
- P. J. Gerber et al., "Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities" (FAO, 2013).
- Pan X F, Wang L, Pan A, 2021. Epidemiology and determinants of obesity in China[J]. *Lancet Diabetes & Endocrinology*, 9(6): 373-392.
- Peñuelas, Josep, Jordi Sardans. 2022. The Global Nitrogen-Phosphorus Imbalance. *Science* 375 (6578): 266-67. <https://doi.org/10.1126/science.abl4827>.
- Poore J & Nemecek T Reducing food's environmental impacts through producers and consumers[J]. *Science*, 2018, 360: 987-92.
- Sánchez-Sánchez M L. Mediterranean diet and health a systematic review of epidemiological studies and intervention trials[J]. 2020: 13.
- Sheng F, Wang J, Chen K Z, et al., 2021. Changing Chinese Diets to Achieve a Win-Win Solution for Health and the Environment[J]. *China & World Economy*, 29(6): 34-52. DOI:10.1111/cwe.12393.
- Springmann M, Mason-D'Croz D, Robinson S, et al. Global and regional health effects of future food production under climate change: a modelling study[J]. *The Lancet*, 2016, 387(10031): 1937-1946. DOI:10.1016/S0140-6736(15)01156-3.
- Springmann M, Spajic L, Clark M A, et al. The healthiness and sustainability of national and global food based dietary guidelines: modelling study[J]. *BMJ*, 2020: m2322. DOI:10.1136/bmj.m2322.
- Springmann, M., Clark, M.A., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L. et al. (2018). Options for keeping the food system within environmental limits[J]. *Nature* 562(7728), 519-525. <https://doi.org/10.1038/s41586-018-0594-0>.
- Steffen W, Richardson K, Rockstrom J, et al., 2015. Planetary boundaries: Guiding human development on a changing planet[J]. *Science*, 347(6223): 1259855. <https://doi.org/10.1126/science.1259855>.
- Thale S, Zessner M, Weigl M, et al., 2015. Possible implications of dietary changes on nutrient fluxes, environment and land use in Austria[J]. *Agricultural Systems*, 136: 14-29. <https://doi.org/10.1016/j.agsy.2015.01.006>.
- Theurl M C, Lauk C, Kalt G, et al., 2020. Food systems in a zero -deforestation world: Dietary change is more important than intensification for climate targets in 2050[J]. *Science of the Total Environment*, 735: 139353. <https://doi.org/10.1016/j.scitotenv.2020.139353>.
- United Nations Environment Programme (2022). Emissions Gap Report 2022: The Closing Window-Climate crisis calls for rapid transformation of societies. Nairobi. <https://www.unep.org/emissions-gap-report-2022>.
- Van De Rest O, Berendsen A A, Haveman-Nies A, et al. 2015. Dietary patterns, cognitive decline, and dementia: a systematic review[J]. *Advances in nutrition*, 6(2): 154-168.
- Wang J, Lin X, Bloomgarden Z T, et al. The jiangnan diet, a healthy diet pattern for Chinese[J]. *Journal of Diabetes*, 2020, 12(5): 365-371. DOI:10.1111/1753-0407.13015.
- Wang J, Sun S, Yin Y, et al., 2022. Water-Food-Carbon Nexus Related to the Producer-Consumer Link: A Review[J]. *Advances in Nutrition*, 13(3): 938-952. <https://doi.org/10.1093/advances/nmac020>.
- Wang Xiao, Qi Ye. Characterization of greenhouse gas emissions from food throughout its life cycle[J]. *China Population, Resources and Environment*, 2013, 23(7): 70-76.
- Wengreen H, Munge R G, Cutler A et al. 2013. Prospective study of Dietary Approaches to Stop Hypertension and Mediterranean-style dietary patterns and age-related cognitive change: the Cache County Study on Memory, Health and Aging[J]. *The American journal of clinical nutrition*, 98(5): 1263-1271.
- Westhoek H, Lesschen J P, Rood T, et al., 2014. Food choices, health and environment: Effects of cutting Europe's meat and dairy intake[J]. *Global Environmental Change-Human and Policy Dimensions*, 26: 196-205. <https://doi.org/10.1016/j.gloenv>



- cha.2014.02.004.
- Willett, W., Johan R, et al. Food in the Anthropocene: the Eat-Lancet Commission on Healthy Diets from Sustainable Food Systems[J]. *The Lancet*, 2019,393(10170):447-492.
- Xing L, Lin T, Xue X, et al., 2021. Urban Metabolism of Food-Sourced Nitrogen among Different Income Households: A Case Study Based on Large Sample Survey in Xiamen City, China[J]. *Foods*, 10(11): 2842. <https://doi.org/10.3390/foods10112842>.
- Xu F, Bai Junfei, Li Lei. Mechanisms of food price effects on improving dietary structure and reducing water demand[J]. *Resource Science*, 2021, 43(12): 2490-2502.
- Yin J, Zhang X, Huang W, et al., 2021. The potential benefits of dietary shift in China: Synergies among acceptability, health, and environmental sustainability[J]. *Science of the Total Environment*, 779: 146497. <https://doi.org/10.1016/j.scitotenv.2021.146497>.
- Yu, D., Zhang, X., et al., 2014. Adherence to Dietary Guidelines and Mortality: A Report From Prospective Cohort Studies of 134,000 Chinese Adults in Urban Shanghai[J]. *American Journal of Clinical Nutrition*(2),693-700.
- Zagmutt FJ, Pouzou JG & Costard S (2020) The EAT-Lancet commission's dietary composition may not prevent noncommunicable disease mortality. *The Journal of Nutrition* 150: 985-8. <https://doi.org/10.1093/jn/nxaa020>.
- Zhang J, Chai L, 2022. Trade-off between human health and environmental health in global diets[J]. *Resources, Conservation and Recycling*, 182: 106336. DOI:10.1016/j.resconrec.2022.106336.
- Zhang M, Feng J C, Sun L, et al., 2022. Individual dietary structure changes promote greenhouse gas emission reduction[J]. *Journal of Cleaner Production*, 366: 132787. <https://doi.org/10.1016/j.jclepro.2022.132787>.
- ZHAO Yao-Yang, Jiang Linlin, Wang Jie. Study on the impact of the changing dietary structure of the population on the demand for land for food production in China[J]. *China Population-Resources and Environment*, 2014, 24(03): 54-60.
- Zhao, L. Y., D. Liu, D. M. Yu, J. Zhang, J. Z. Wang et al., 2018, "Challenges brought about by rapid changes in chinese diets: Comparison with developed countries and implications for further improvement," *Biomedical and Environmental Sciences*, Vol. 31, pp. 73-78.

Chapter 2

Healthy Diets in China

Qiran Zhao,^{1,2} Xinyue Ding,^{1,2} Chen Zhu,^{1,2} Wenhua Zhao,³ Shenggen Fan,^{1,2}
Liyun Zhao,³ Dongmei Yu³

1. Academy of Global Food Economics and Policy, China Agricultural University

2. College of Economics and Management, China Agricultural University

3. National Institute for Nutrition and Health (NINH) of the Chinese Center for Disease Control and Prevention



Key Findings

- As China's national income increases, the problem of dietary imbalance is becoming increasingly evident. The proportion of overweight and obese people continues to rise, and incidences and risks of chronic diseases are on the rise. The impact of dietary imbalance on health therefore requires close attention.
- The trend toward the Westernization of Chinese residents' dietary structure is evident, with significant differences from the recommendations of the Chinese Dietary Guidelines. Dietary trends show an excessive intake of meat and fats, while the intake of whole grains, beans, vegetables, and fruits is inadequate. In terms of nutrients, dietary fiber, vitamin A, and zinc are generally under consumed.
- Due to differences in food resource endowments, climate and geographic environments, culture, religious beliefs, population density, and other factors, there are significant differences in food and nutrient intake among residents in different regions of China. Therefore, more research is required on the characteristics and dietary habits of the Chinese population, and dietary guidelines should be tailored to regional resource endowments and the dietary preferences of residents.

Policy Recommendations

- Chinese residents should be encouraged to consume a reasonable amount of whole grains, fruits, and legumes and to reduce their consumption of refined grains and red meat through policy guidelines and economic incentives.
- More research is required on the dietary structure and nutritional health of the Chinese population to ensure a timely improvement. Dietary guidelines should be updated based on changes in the dietary habits of Chinese residents and the challenges they face. It is also necessary to strengthen the promotion of Dietary Guidelines for Chinese Residents to increase dietary awareness and promote national nutritional health.
- Each region should develop strong and regionally appropriate dietary guidelines and recommendations based on local characteristics.
- It is also necessary to pay greater attention to hidden hunger caused by an insufficient intake of micronutrients and provide multiple food substitution options to improve dietary conditions. Effective, scientifically based interventions should be implemented to improve and address specific micronutrient deficiencies in different regions, such as increased intake of food rich in nutrients, food fortification, and nutrient supplements.



2.1 Introduction

Regions develop distinctive culinary cultures and dietary preferences over time based on the availability of food resources, climate, geographic environment, culture, religious beliefs, population density, and other factors. However, regional dietary patterns are not set in stone. A large body of research has demonstrated that economic development (e.g., urbanization, income growth, and price fluctuations), social evolution (e.g., changes in lifestyle and female empowerment), cultural transformation (e.g., religious beliefs and environmentalism), and technological advancements (e.g., food production, processing, storage, and cooking techniques) can all influence residents' dietary structure and preferences. International studies have shown that different regions have different dietary structure, such as the Mediterranean diet and the Western diet in Western countries and traditional Korean, Japanese, and Chinese diets in Asian countries. Aside from genetic and environmental factors, dietary quality and patterns have a significant impact on chronic and noncommunicable diseases. The World Health Organization has emphasized the need to "restrain unreasonable diets" in its Global Action Plan for the Prevention and Control of Noncommunicable Diseases.

Due to its vast geographical area, diverse agricultural products, varying dietary habits, and differing living standards, China's regions exhibit significant differences in diets. As China's industrialization, urbanization, and aging processes continue to accelerate, simply converting survey data into standard populations or presenting data using a binary structure of urban and rural areas is of little help when implementing a national nutrition plan or scientifically adjusting and establishing a national dietary structure. There is still a lack of in-depth research on the dietary structures of China's different regions, which makes it difficult to optimize residents' dietary habits. To investigate the dietary structure of residents in various regions of China, this chapter uses data from the China Nutrition and Health Surveillance (2015) to present the intake of different food groups, macronutrients, and micronutrients in the diets of residents in seven major regions of China.¹ Based on Chinese Dietary Guidelines (2022) and Chinese Dietary Reference (2013), this chapter examines the dietary structure of residents in seven major regions of China

¹As a result of the lack of relevant data on the consumption of edible oils, we used as a substitute the average daily cooking oil intake per capita of China's different populations, as reported in the "Report on Nutrition and Chronic Disease Status of Chinese Residents" (2020) by the National Health Commission's Disease Control and Prevention Bureau.



from several dimensions, including the intake levels of food groups and nutrients; the proportional intake of the three major macronutrients; and the sources of energy, nutrients, and the three major macronutrients.

2.2 A Comparison of Different Dietary Patterns

Healthy dietary patterns are often described as rich in foods that promote health, including plant-based foods, fresh fruits and vegetables, and animal-based proteins (Cena and Calder 2020), but these patterns vary across different countries and regions (Dai et al. 2021).

The Dietary Approaches to Stop Hypertension (DASH) diet is a dietary pattern that promotes the consumption of fruits, vegetables, and low-fat dairy products. It is mainly popular in Western countries, such as the United States. The DASH dietary recommendations require adherents to consume one to two servings of fruit, four to five servings of vegetables, seven to eight servings of whole grains (e.g., a slice of bread, a cup of instant oatmeal, or half a cup of cooked rice or pasta), two to three servings of low-fat or fat-free dairy products, no more than two servings of lean meat protein (e.g., beef, lamb, or pork), and four to five servings of nuts per week (Campbell 2017).² Multiple studies have shown that the DASH diet has a significant impact on lowering blood pressure (Appel et al. 1997; Siervo et al. 2015).

The Mediterranean diet is a traditional dietary pattern in European Mediterranean countries that refers to not only the types of food consumed and their relative contributions to daily nutrient intake but also dietary methods that consider food sources, cooking and consumption methods, and lifestyle factors (Bach-Faig et al. 2011). The Mediterranean diet requires adherents to consume one to two servings of fruit per day, more than two servings of vegetables per meal, one to two servings of whole grains, two servings of low-fat dairy products, one to two servings of nuts, and less than two servings of red meat and two servings of white meat per week, with processed meat consumption limited to a maximum of one serving per week (Bach-Faig et al. 2011).³ Several studies have shown that the Mediterranean diet can

prevent various chronic diseases (Estruch et al. 2013; Panagiotakos et al. 2005; Guallar-Castillón et al. 2012).

The traditional Japanese dietary pattern is characterized by a high intake of seafood such as fish and shrimp, rice, vegetables, beans, and green tea. The Japanese dietary pattern is characterized by a balanced diet structure, a variety of food, and moderate energy intake and is rich in nutrients such as dietary fiber, vitamins, and minerals. The recommended food types in the traditional Japanese dietary pattern include five to seven servings of staple foods; five to six servings of side dishes made from vegetables, potatoes, beans, mushrooms, and seaweed; and three to five servings of main dishes made from meat, eggs, fish, soybeans, and their products. The diet also recommends a daily intake of two servings of milk and dairy products and two servings of fruit. Studies have shown that the traditional Japanese dietary pattern can reduce the risk of death associated with cardiovascular disease (Sadakane et al. 2008), help to prevent diabetes (Morimoto et al. 2012), and reduce incidences of cancer (Mizoue et al. 2005; Kurotani et al. 2010).

2.3 The Characteristics of Chinese Cuisine

Compared to healthy Western diets, traditional Chinese diets include more aquatic and soy products. In China, the nutritional value of aquatic products and soy products has received increasing attention from health-conscious consumers. Protein is a crucial component of the human body, and almost all forms of immune function are affected by protein-energy malnutrition. As one of the main sources of animal protein, aquatic products are rich in protein, fatty acids, carbohydrates, vitamins, and important trace elements (Zhong et al. 2018). The Chinese Dietary Guidelines (2022), which is published by the Chinese Nutrition Society, recommends consuming aquatic products at least twice a week as part of a healthy diet (Chinese Dietary Guidelines for Residents 2022). A study on the effect of long-chain n-3 polyunsaturated fatty acids in seafood on cardiovascular disease found that consuming seafood one to two times a week could significantly reduce the risk of coronary heart disease, congestive heart failure, sudden cardiac death, and ischemic stroke (Rimm et al. 2018).

Soy products are known as “plant meat” and are

²Food portions in the DASH diet are based on a daily target of 2,000 calories for one individual.

³The serving sizes in the Mediterranean diet are based on local customs and traditions.



an important source of protein (Luo et al. 2016). The protein digestibility and absorption rate of tofu can reach more than 90 percent, whereas the protein digestion rate of soymilk can reach only 84.9 percent. A study that conducted a meta-analysis to explore the relationship between soy intake and gastric cancer risk found that a high intake of soybeans, tofu, and soy milk is associated with a reduced risk of gastric cancer (soybeans, odds ratio [OR] = 0.75, 95 percent confidence interval [CI] = 0.66–0.85; tofu, OR = 0.77, 95 percent CI = 0.68–0.88; soy milk, OR = 0.78, 95 percent CI = 0.65–0.94) and that increasing soy intake can reduce the risk of gastric cancer (Ni et al. 2018). Simultaneously, oligosaccharides contained in soybeans can effectively improve lipid metabolism and lower blood lipid and cholesterol levels in the body (Li, Q et al. 2017).

In addition to improving metabolic syndrome, legume-based foods have inhibitory effects on breast cancer, cervical cancer, and other diseases. Research conducted on Asian populations has shown that soy has a protective effect against breast cancer in Asian women (Zhong Xiao, Zhang Caixia 2012). After examining protein sources, a study found that the effect of plant proteins on lipid-related indicators was mainly positive, whereas the effect of animal proteins was negative (Lee et al. 2014). A reasonable intake of vegetables, fish, beans, and milk can effectively reduce overall mortality and prevent chronic diseases such as cardiovascular and cerebrovascular diseases and significantly improve the health of the population. Studies have confirmed that an increase in the intake of vegetables (about 350–420 grams per day) and fish (about 80 grams per day) can effectively reduce the risk of overall mortality, cardiovascular and cerebrovascular diseases, and other chronic diseases (Toh et al. 2020; Matsuyama et al. 2021; Ojagbemi et al. 2021).

A study of Chinese men with a high risk of developing cardiovascular and cerebrovascular diseases found that increasing salmon intake in their daily diet for eight weeks resulted in significant reductions in cardiovascular inflammation and triglycerides in the blood, which significantly improved their high-density cholesterol environment (Zhang et al. 2010). Similar studies have found that fish species that are rich in long-chain fatty acids, EPA (eicosapentaenoic acid), and DHA (docosahexaenoic acid) can effectively reduce the onset

of cardiovascular and cerebrovascular diseases (Jayedi et al. 2018; Sala-Vila et al. 2022). In addition, some studies have identified low cholesterol/antidiabetic peptides in soy and winged bean protein hydrolysates as well as low blood pressure/antidiabetic peptides in milk protein hydrolysates (Lammi et al. 2019). Bioactive peptides derived from food proteins have a significant effect on preventing cardiovascular diseases and improving health.

With economic development and higher standards of living, problems associated with dietary imbalance have become increasingly severe. An overconsumption of animal-based foods, particularly red meat, along with a high intake of cooking oil and salt have contributed to an increasing prevalence of chronic diet-related diseases, such as overweight and obesity, hypertension, and diabetes. In recent years, China's traditional dietary structure has undergone a significant transformation, with dietary intake and nutrient compositions shifting from traditional to Westernized eating patterns. China has a rich culinary culture that has influenced other countries' cuisines, but it has likewise been influenced by other countries, particularly in by the Western diet (Yang 2014). The Chinese dietary structure has shifted from traditional foods, such as large amounts of grains and vegetables and small amounts of animal-based foods, to a diet that is high in fat and low in carbohydrates and fiber (Zhai et al. 2014; Du et al. 2014; Du et al. 2004).

A systematic review of eight countries, including China, found a positive correlation between the consumption of red meat, processed meat, and refined carbohydrates and the risk of colon and rectal cancer (Azeem et al. 2015). Epidemiological evidence on the association between meat consumption and the risk of colorectal cancer—based on 32 case-control studies and 13 cohort studies—supported the hypothesis that meat consumption slightly increased the risk of colorectal cancer. This association with red meat and processed meat was more pronounced (Norat and Riboli 2009).

Regarding the risk of developing type 2 diabetes, a cohort study on meat consumption and type 2 diabetes risk showed that a high intake of red meat and processed meat increased the risk of developing type 2 diabetes, with relative risks of 1.21 (95 percent CI 1.07–1.38) and 1.41 (95 percent CI 1.25–1.60), respectively (Aune et al. 2009). A case-control study of 16,822 Chinese individuals found that compared to those who consumed 33.3 grams



of animal meat per day, those who consumed 75 grams, 116.7 grams, and 191.7 grams of animal meat per day had increased risks of obesity (body mass index > 24) by 9 percent, 14 percent, and 27 percent, respectively, with ORs (95 percent CI) of 1.09 (0.94, 1.26), 1.14 (0.98, 1.33), and 1.27 (1.07, 1.49), respectively (Wang et al. 2014).

High salt (sodium) intake increases the risk of chronic diseases such as hypertension, cardiovascular disease, and stroke. A study conducted in six countries, including China, found that an increase in sodium intake led to an increase in coronary heart disease mortality, with a relative risk (95 percent CI) of 1.32 (1.13, 1.53) (Hamley 2017). Studies have shown that compared to individuals with a sodium intake of <3.2 grams per day, Chinese individuals with a sodium intake of ≥ 7.6 grams per day have an 84 percent higher risk of developing hypertension (Huang et al. 2020).

An irrational dietary structure leads to an inadequate intake of micronutrients and an increased risk of micronutrient deficiencies, mainly deficiencies in vitamin A, iron, and zinc. Vitamin A, iron, and zinc are important micronutrients that affect immune function. Long-term deficiencies can cause problems such as stunted development in children and increased health risks in adults. Long-term iron deficiency can lead to anemia, while vitamin A deficiency can lead to night blindness and other diseases (McCann JC and Ames BN 2007; Sommer et al. 1998; Pierce et al. 1998). The Report on the Nutrition and Chronic Disease Status of Chinese Residents (2020) estimated the anemia rate among adult residents of China at 8.7 percent, with higher rates among children younger than 6 (21.2 percent), pregnant women (13.6 percent), and lactating women (17.2 percent); the marginal vitamin A deficiency rate among children and adolescents age 6 to 17 years was 14.7 percent. A meta-analysis involving 292,877 healthy children and adolescents from 55 studies found that the zinc deficiency rate among children younger than 14 was as high as 27.0 percent (Cai-Jin Y et al. 2021).

Micronutrient deficiencies can be ameliorated by increasing the consumption of foods rich in these nutrients, fortifying foods, or using nutrient supplements (Baltussen et al. 2004; West 2005; Mukherjee and Ilangantileke 2002). The main advantage of nutrient supplements is that they are easy to administer and can quickly increase intake levels, but their effectiveness and

safety are still subject to some debate. Food fortification mainly faces policy and technological challenges. Diversifying food intake is a safer and more reliable way to achieve micronutrient intake; however, acceptance and affordability issues may arise due to differences in dietary habits (Ma et al. 2008; Allen 2003; Copenhagen Consensus Center 2004).

2.4 Regional Differences in the Dietary Structure of Chinese Residents

China is a vast country and home to diverse dietary customs among its regional populations. To comprehensively understand the dietary structures of residents from different regions in China, this chapter employs data from the China Nutrition and Health Surveillance (2015), which is based on food frequency questionnaire (FFQ). By analyzing and comparing the food intake levels, and dietary quality of residents from various regions, we are able to ensure the comparability of the data by standardizing the research objects according to standard population coefficients. Due to the lack of data on participants' physiological status and labor intensity, this study assumes that adults in the standard population have a normal physiological status and low labor intensity. Standard population coefficients are calculated based on sex and age data, leading to an overestimation of the intake of various foods and nutrients in residents' diets.

2.4.1 Current Status of Regional Residents' Dietary Structure in China

(1) Distribution of food group intake by region

China's seven administrative regions are divided based on multiple dimensions, such as geography, history, and ethnic culture, to reflect differences in dietary habits and food supply characteristics. The North China region includes Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia; the East China region includes Shanghai, Jiangsu, Zhejiang, Shandong, and Anhui; the Northeast region includes Liaoning, Jilin, and Heilongjiang; the Central China region includes Hubei, Hunan, Henan, and Jiangxi; the South China region includes Guangdong, Guangxi, Hainan, and Fujian; the Southwest region includes Sichuan, Chongqing, Guizhou, Yunnan, and



Tibet; and the Northwest region includes Shaanxi, Gansu, Xinjiang, Qinghai, and Ningxia (Third National Climate Change Assessment Report Writing Committee 2015; Chinese Chapter of the Open Source Geospatial Foundation 2016; Xie, H. et al. 2006).⁴

This chapter examines the daily intake levels of grains, potatoes, vegetables, fruits, animal-based foods, milk and dairy products, and soy and nut food groups among the residents of China's seven administrative regions to understand regional food intake preferences. To ensure the additivity of various foods, this study converts foods such as youtiao, youbing, fried cakes, and instant noodles into the weight of wheat flour based on their corresponding carbohydrate content in the China Food Composition Table (standard version 6) and converts foods such as soy milk, doufunao, tofu, fuzhu, and tofu slices into the weight of soybeans based on their corresponding protein content. Full-fat liquid milk, low-fat and skimmed liquid milk, whole milk powder, low-fat milk powder, yogurt, and cheese are converted into the weight of fresh cow's milk based on their corresponding protein content. Dried mushrooms, dried fungus, and dried seaweed are converted into their respective weights based on moisture content.

According to The Chinese Dietary Guidelines (2022), food groups are then classified into seven categories, including grains, potatoes, vegetables, fruits, animal-based foods, milk and dairy products, and soy and nut food groups, and the intake of each food group is accumulated within the group. The grain category includes rice and processed products, wheat flour and processed products, other grains and processed products, corn and processed products, and youtiao, youbing, and instant noodles. Animal-based foods include pork, beef, mutton, poultry, other meats, animal organs, meat processed products, fish, shrimp, crab, and egg. Dairy and dairy processed products include full-fat liquid milk, low-fat and skimmed liquid milk, whole milk powder, low-fat milk powder, yogurt, and cheese. The soy and nut food group includes soybeans, soy milk, doufunao, tofu, fuzhu, tofu slices, and nuts. Overall, there are significant regional differences in food intake preferences. The specific characteristics of the intake

⁴Due to the lack of official divisions in the seven major administrative regions, there is inconsistency in the allocation of certain provinces. This paper considers geographical conditions, climate factors, and dietary habits comprehensively and proposes this version as the division of the seven major administrative regions in this study.

preferences for each food group are as follows (Figure 2.1).

Cereal intake reveals regional disparities, with residents in Northeast China and North China having a lower daily cereal intake than those in other regions. Almost one-fourth of residents in Northeast China and North China consume less than the lower bound of 200 grams of the recommended daily intake range, while nearly half exceed the upper bound of 300 grams. In all the other regions, more than half of the residents' cereal intake exceeds the upper bound recommended by dietary guidelines.

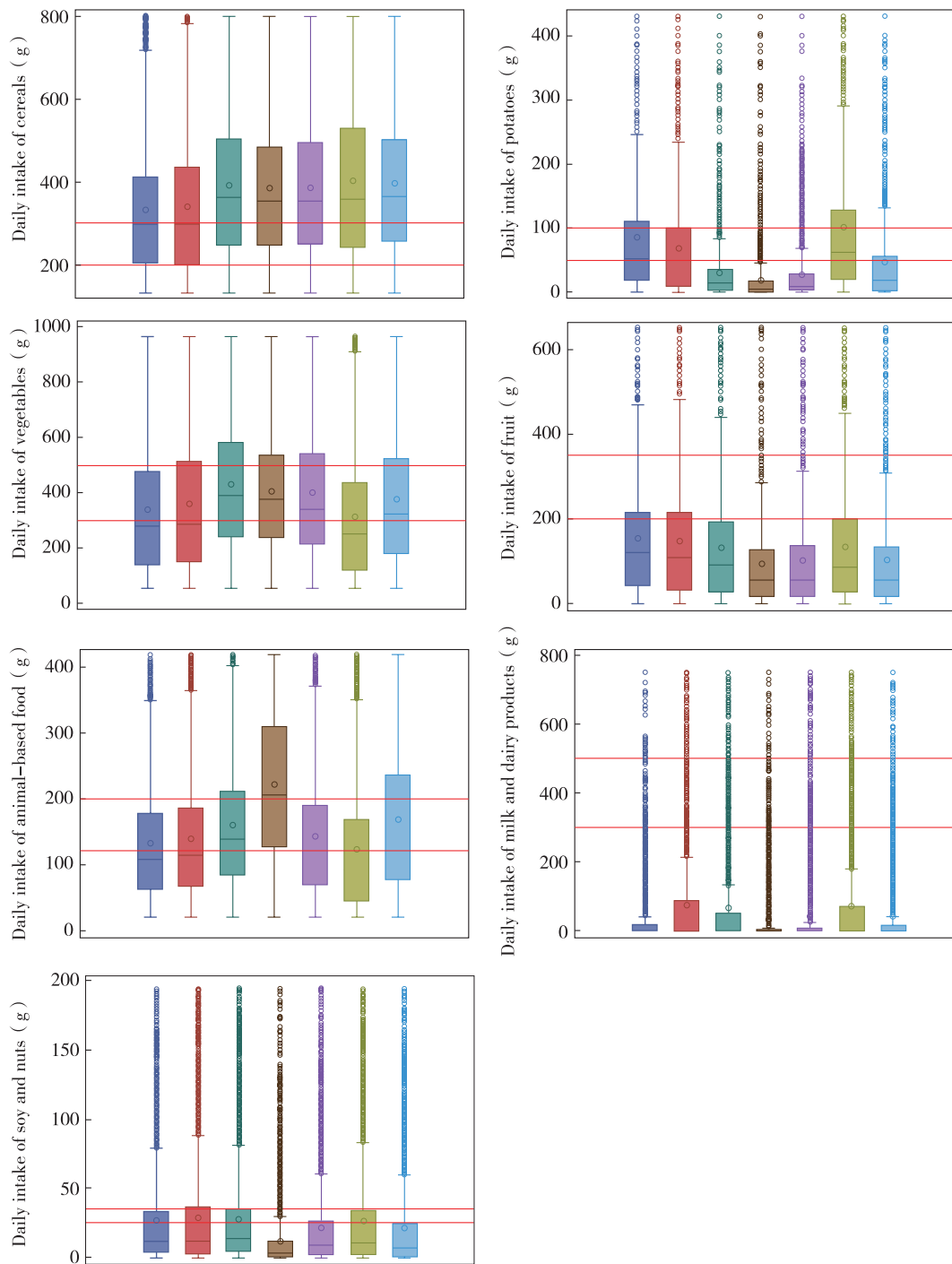
Potato intake also reveals significant regional disparities, with residents in East China, South China, Central China, and Southwest China consuming less potato-based food on a daily basis compared to those in other regions. More than three-fourths of the residents in East, South, and Central China have a daily intake of potato-based food that is below the lower bound of 50 grams recommended by the dietary guidelines. Similarly, almost three-fourths of the residents in Southwest China eat less potato-based food than the recommended lower bound. In the other regions, nearly half of the residents consume less potato-based food than the recommended lower bound.

Vegetable intake reveals similar disparities across regions, with residents in the Northeast, North, Northwest, and Southwest regions eating less vegetables compared to other regions. In particular, more than half of the residents in the Northeast, North, and Northwest regions have a vegetable intake that is below the lower bound of the recommended daily intake of 300 grams, while nearly half of the residents in the Southwest region fall below this bound. In the other regions, more than a quarter of the residents consume fewer vegetables than the lower bound recommended by dietary guidelines.

The distribution of fruit intake indicates that residents across all regions eat less fruit than the lower bound of the daily intake recommended in the dietary guidelines. The problem of insufficient fruit intake is particularly severe in South, Central, and Southwest China, with more than three-quarters of the residents consuming less than the lower bound of the recommended daily intake (200 grams). Even in other regions, nearly three-quarters of the residents consume less than the lower bound of the recommended daily intake.



Figure 2.1 Regional distribution of daily intake by food groups



Explanatory legend:

(1) ■ Northeast China ■ East China ■ North China ■ Central China ■ South China ■ Northwest China ■ Southwest China

(2) Figure 2-1 shows the distribution of daily intake of food groups by residents in different regions using boxplot. The five lines from top to bottom are the upper edge line, upper quartile Q3, median, lower quartile Q1, and lower edge line. Where the upper edge line = $Q3 + 1.5 \times \text{interquartile spacing}$; Lower edge line = $Q1 - 1.5 \times \text{interquartile spacing}$; Interquartile spacing = $Q3 - Q1$. The average value is represented by the original points on the boxplot. Points outside the upper and lower edge lines indicate other values (usually outliers, or more outliers indicate discrete values).

(3) The upper and lower red lines in the figure respectively represent the upper and lower bound of the recommended intake values of corresponding foods in the Chinese Food Guide Pagoda (2022).

Source: China Nutrition and Health Surveillance (2015)



The distribution of animal-based food intake shows that daily consumption of animal-based foods is much higher in South China than in other regions, and the problem of an excessive intake of animal-based foods needs to be addressed. More than half of the residents in South China consume more animal-based foods than the upper bound (200 grams) of the daily intake range recommended by the dietary guidelines. In contrast, residents in other regions need to pay attention to an insufficient intake of animal-based foods. In Northeast, North, and Northwest China, more than half of the residents consume less animal-based foods than the lower bound (120 grams) of the recommended daily intake range.

The daily intake of milk and dairy processed products across all regions is far below the lower bound of the recommended daily intake range (300 grams).

The distribution of soybean and nut food intake reveals that residents in all regions are facing the problem of insufficient intake. The situation is particularly severe in South China, Central China, and Southwest China, where more than 75 percent of the residents consume fewer soybeans and nuts than the lower bound (25 grams) of the recommended daily intake in the dietary guidelines. In other regions, more than half of the residents consume fewer soybeans and nuts than the

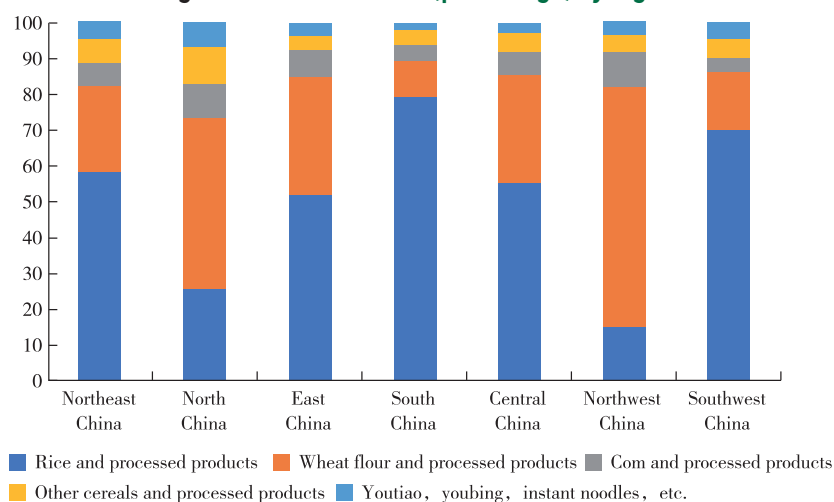
lower bound of the recommended daily intake range.

(2) Food intake (percentage) in each food group by region

The analysis of the food choices of residents in different regions is based on the results of the distribution of intake of each food group and data from the food frequency questionnaire (FFQ) survey for each food group. The analysis focuses on the three major food groups—cereals, animal-based foods, and soybeans and nuts—to examine the food preferences of residents in different regions and provide a scientific and theoretical foundation for recommended dietary guidelines that are tailored to specific regions. The analysis highlights the following specific characteristics.

Preference for cereal food choices. The intake of corn and other cereals and processed products is relatively higher in Northeast, North, and Northwest China. There were also significant regional differences in residents' preferences for rice and wheat and processed products. Residents in Northwest and North China show a higher intake of wheat and processed products, whereas residents in Northeast, East, and Central China have a higher intake of rice and processed products. Residents in South China and Southwest China had a significantly higher preference for rice and processed products than for wheat and processed products (Figure 2.2).

Figure 2.2 Cereal intake (percentage) by region



Source: China Nutrition and Health Surveillance (2015)

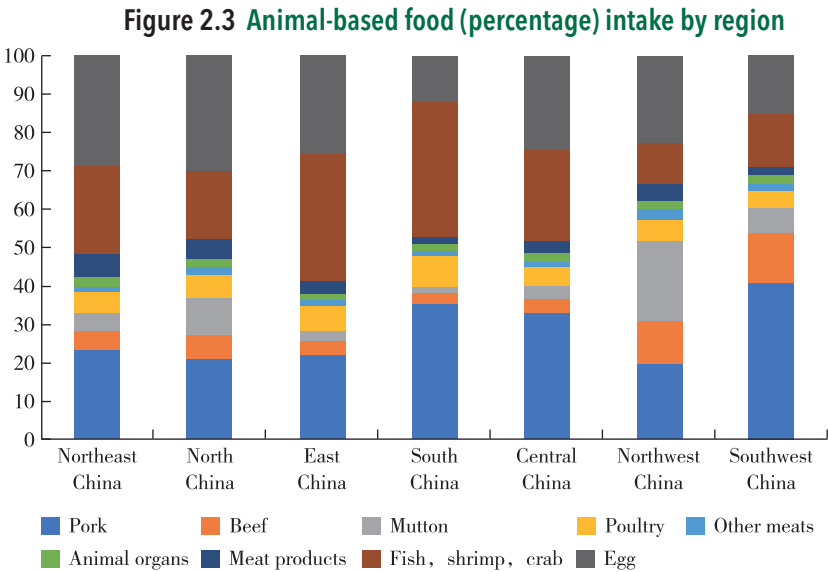
Note: Youtiao, youbing, instant noodles, and so forth are converted to wheat flour weight according to their carbohydrate content.

Preference for animal-based foods. Residents in South China, Central China, and Southwest China consume a higher proportion of pork than other regions.

Residents in Northwest China and Southwest China consume a higher proportion of beef; residents in Northwest China and North China consume a higher

proportion of mutton; and residents in East China and South China consume a higher proportion of fish, shrimp, crab, and shellfish than do residents in other regions.

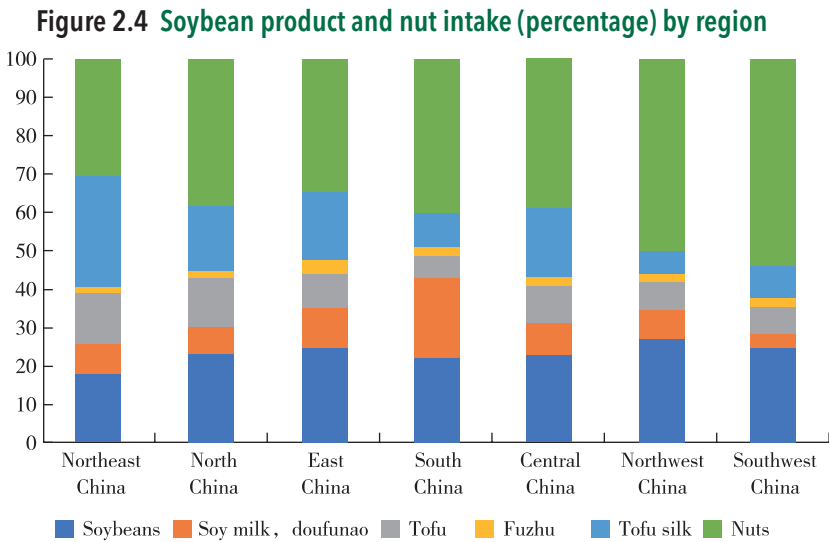
Residents in Northeast China, North China, East China, Central China, and Northwest China eat more eggs than those in other regions (Figure 2.3).



Source: China Nutrition and Health Surveillance (2015)

Preference for soybean and nut foods. Residents in South China have a significant preference for soymilk and doufunao compared to those living in other regions,

whereas residents in Northeast China eat more tofu slices than those living in other regions (Figure 2.4).



Source: China Nutrition and Health Surveillance (2015)

Note: Soymilk, doufunao, tofu, fuzhu, tofu slices, and so forth are converted to soybean weight according to their protein content.

(3) Intake frequency of potatoes, fruits, milk, milk products, and soybeans and nuts by region

Based on the regional distribution of intake by food group and the data collected from the FFQ for each food group, this section analyzes the consumption frequency of underconsumed foods, including potatoes, fruits, milk and dairy products, and soybeans and nuts. The goal is to

gain a better understanding of residents' food selection preferences in these groups and provide a scientific basis for recommended regional dietary guidelines. The key findings are as follows.

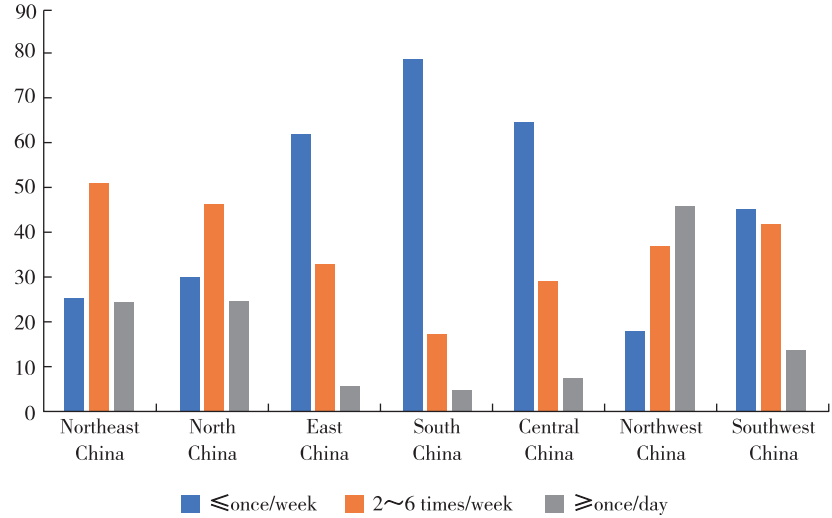
Average weekly intake frequency of potatoes. More than 60 percent of residents in East, South, and Central China consume potatoes not higher than once a week,

whereas nearly half of the residents in Northwest China consume potatoes once a day or more (Figure 2.5).

Average weekly fruit intake frequency of residents in different regions. More than half of the residents in Northeast and North China consume fruit at least

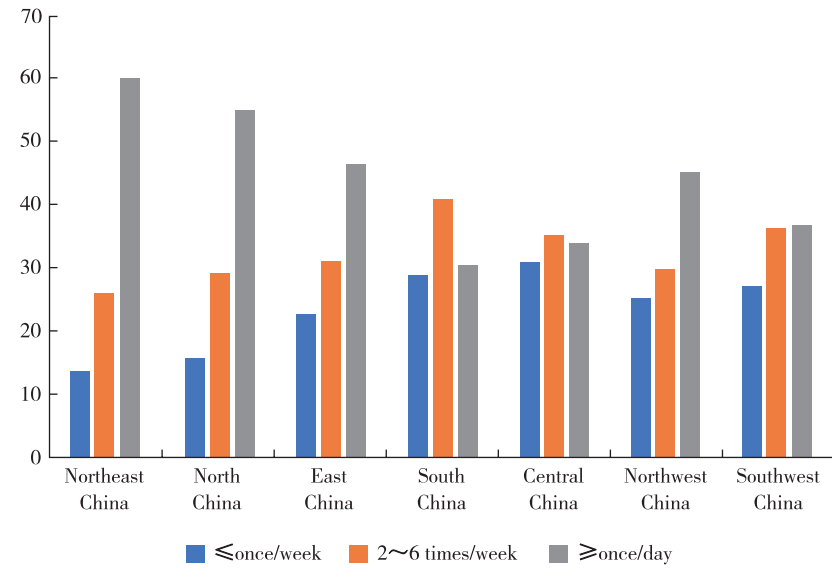
once a day, and nearly half of the residents in East and Northwest China consume fruit once a day or more. A higher proportion of residents in South, Central, and Southwest China consume fruit less than once a day (Figure 2.6).

Figure 2.5 Average weekly intake frequency of potatoes by region (percentage)



Source: China Nutrition and Health Surveillance (2015)

Figure 2.6 Average weekly intake frequency of fruit by region (percentage)



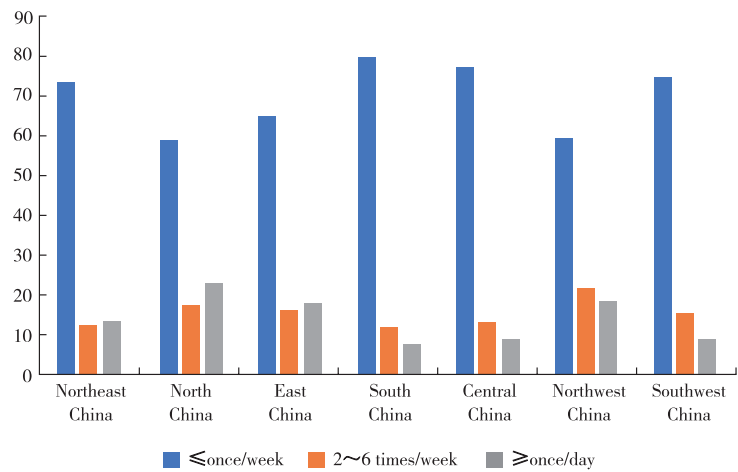
Source: China Nutrition and Health Surveillance (2015)

Average weekly intake frequency of milk and dairy products. More than half of residents across all regions consume milk and dairy products not higher than once a week; however, approximately 20 percent of residents in North, East, and Northwest China consume milk and dairy products once a day or more (Figure 2.7).

Average weekly intake frequency of soybeans and nuts in different regions. The intake frequency of

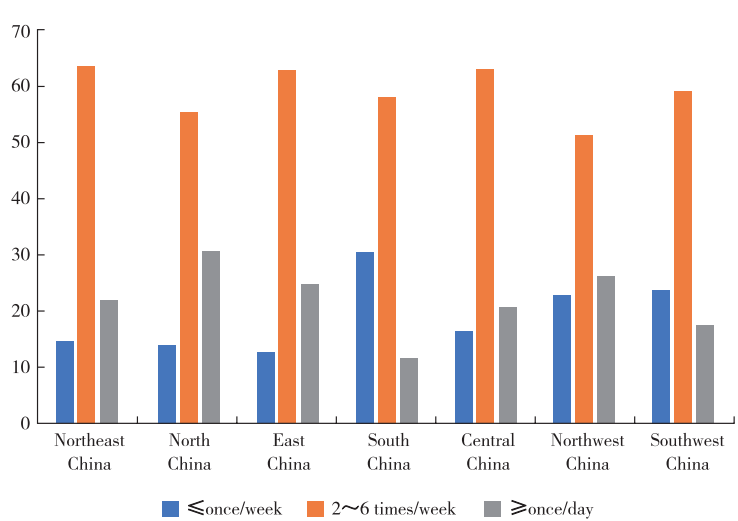
soybeans and nuts across all regions is concentrated between two and six times per week. In China, the overall intake frequency of soybeans and nuts is low, with more than 30 percent of residents consuming items from this food group not higher than once a week and only approximately 10 percent consuming them once a day or more (Figure 2.8).

Figure 2.7 Average weekly intake frequency of milk and milk products by region (percentage)



Source: China Nutrition and Health Surveillance (2015)

Figure 2.8 Average weekly intake frequency of soybeans and nuts by region (percentage)



Source: China Nutrition and Health Surveillance (2015)

2.4.2 Assessment of the Quality of Dietary Structure of Residents by Region in China

(1) Energy and protein intake assessment

This section presents the daily intake levels of energy, protein, carbohydrates, fat, and the three macronutrients for the residents of China’s seven administrative regions. The dietary quality of each region’s residents was evaluated by assessing their energy and protein intake levels as well as their energy supply ratios of macronutrients. The study used data from the FFQ to obtain the average daily intake of each food item by region based on a “standard person” (see section 2.4.1 [1] for the regional distribution by food group). Using the most common foods in each food group as representatives, the corresponding energy

and nutrients were obtained from the China Food Composition Table (standard version, sixth edition), and the daily intake of energy, protein, carbohydrates, fat, and the three macronutrients was cumulatively calculated for residents (standard person) in the different regions of China. The specific characteristics are as follows.

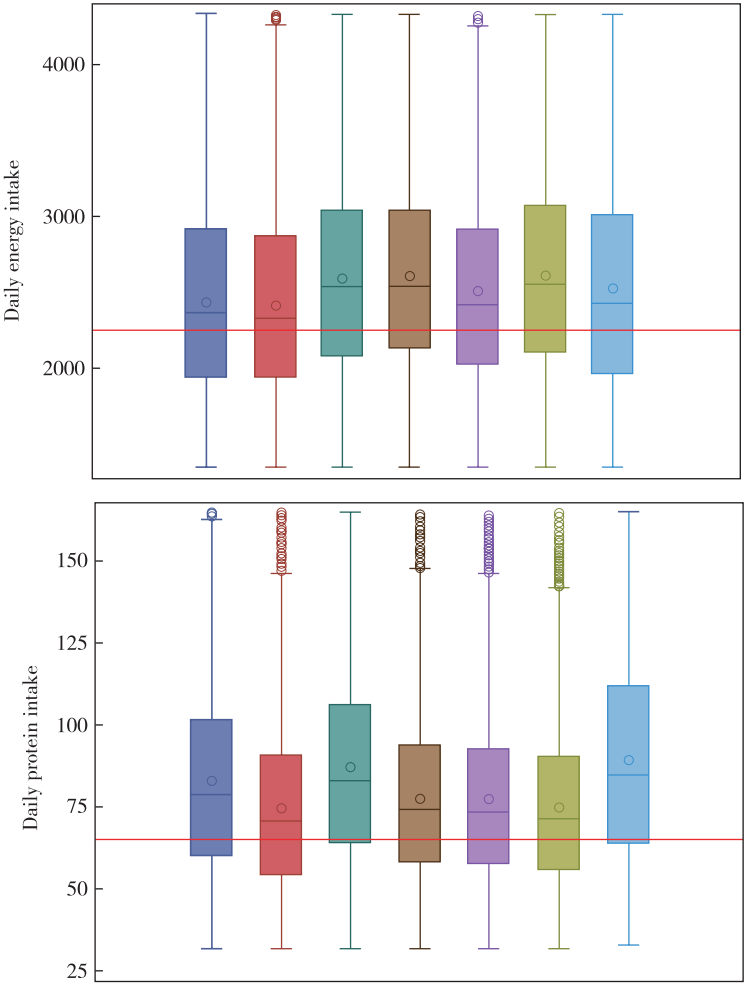
A chart of the regional distribution of energy intake reveals that residents across all regions have problems with excessive energy intake, with higher values in East, South, and Southwest China. At the same time, 25 percent of the residents in North China, Northeast China, and Northwest China have an energy intake of less than 2,000 kilocalories per day (standard person), which needs attention. However, this conclusion should be used only to evaluate relative regional differences in energy intake levels due to the potential of overestimating energy

intake. There are two main reasons for overestimation: first, the data collected by the FFQ survey used in this chapter for assessing dietary energy intake have high requirements for the subject's subjective recall and food weight assessment, which poses a risk of overestimation. Second, when calculating the standard human factor, due to the lack of data on labor intensity and physiological status, the evaluation was uniformly based on low labor intensity and normal physiological status, which poses a risk of overestimation. In addition, due to the lack of information about cooking oil intake in the FFQ data from the China Nutrition and Health Surveillance (2015), the average per capita daily intake of cooking oil for

the different age groups was taken from Report on the Nutrition and Chronic Diseases Status of Chinese Residents (2020), which is published by the China's Disease Control and Prevention Bureau of National Health Commission, as a substitute for regional edible oil intake levels, which may introduce bias (Figure 2.9).

The distribution of protein intake levels shows that across all regions, more than 25 percent of the residents' daily protein intake is lower than the recommended dietary reference intake (65 grams per day), particularly in the Northeast, South, Central, Southwest, and North regions (Figure 2.9).

Figure 2.9 Regional distribution of daily energy and protein intake of a standard person (percentage)



Explanatory legend:

- (1) ■ Northeast China ■ East China ■ North China ■ Central China ■ South China ■ Northwest China ■ Southwest China
- (2) Figure 2-9 Boxplot is used to show the distribution of daily energy and protein intake of standard people in different regions. The five lines from top to bottom are the upper edge line, upper quartile Q3, median, lower quartile Q1, and lower edge line. Where the upper edge line = $Q3 + 1.5 \times \text{interquartile spacing}$; Lower edge line = $Q1 - 1.5 \times \text{interquartile spacing}$; Interquartile spacing = $Q3 - Q1$. The average value is represented by the original points on the boxplot. Points outside the upper and lower edge lines indicate other values (usually outliers, or more outliers indicate discrete values).
- (3) The red line in the figure represents the standard recommended human intake of energy/protein in the China Food Composition Table (standard version, sixth edition).

Source: China Nutrition and Health Surveillance (2015)

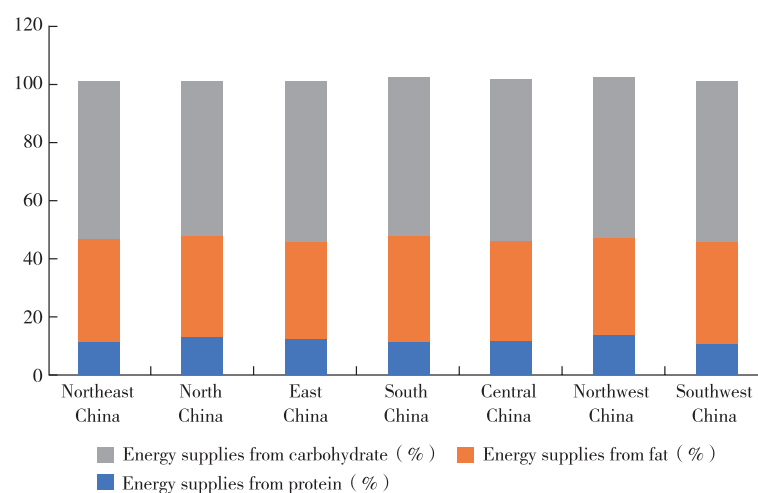


(2) Energy supply ratio of calorogenic nutrients

The energy supply ratio of the three major calorogenic nutrients—protein, fat, and carbohydrates—is defined in terms of their proportional contribution to total dietary energy. It is one of the most frequently used methods to evaluate the rationality of a dietary structure. According to Chinese Food Guide Pagoda (2022), a balanced diet should consist of carbohydrates accounting for 50 to 65 percent of dietary energy; protein, 10 to 15 percent; and fat, 20 to 30 percent. This section uses the data of the China Nutrition and Health Surveillance (2015) to calculate the average energy supply ratios (percentage) of the three primary

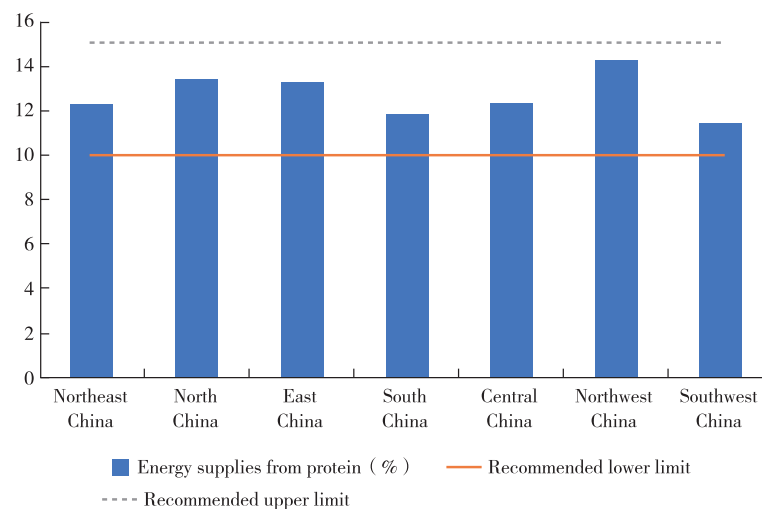
calorogenic nutrients for each region and compares the results to the recommended range. The analysis reveals no significant regional differences in the average energy supply ratios of the three major calorogenic nutrients, and the energy supply ratios of dietary protein were within the recommended range. However, the energy supply ratios of fat exceeded the recommended upper limit (30 percent) across all regions, with the most substantial deviations observed in South China. Although the energy supply ratios of carbohydrates were within the recommended range (50 to 65 percent), North China's ratios were close to the lower limit of the recommended range (50 percent) (Figures 2.10–2.13).

Figure 2.10 Energy supply ratios of energy-producing nutrients by region (percentage)



Source: China Nutrition and Health Surveillance (2015)

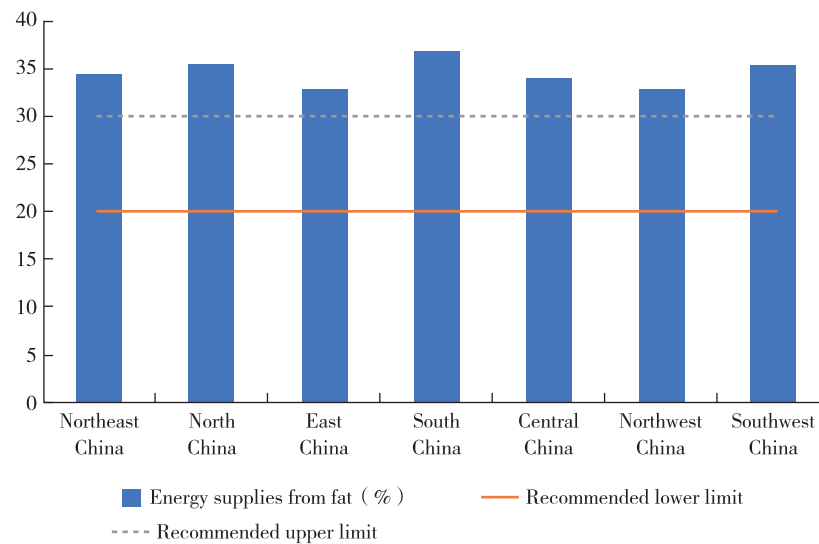
Figure 2.11 Regional comparison of the energy supply ratios of protein (percentage) and recommended intake levels



Source: China Nutrition and Health Surveillance (2015)

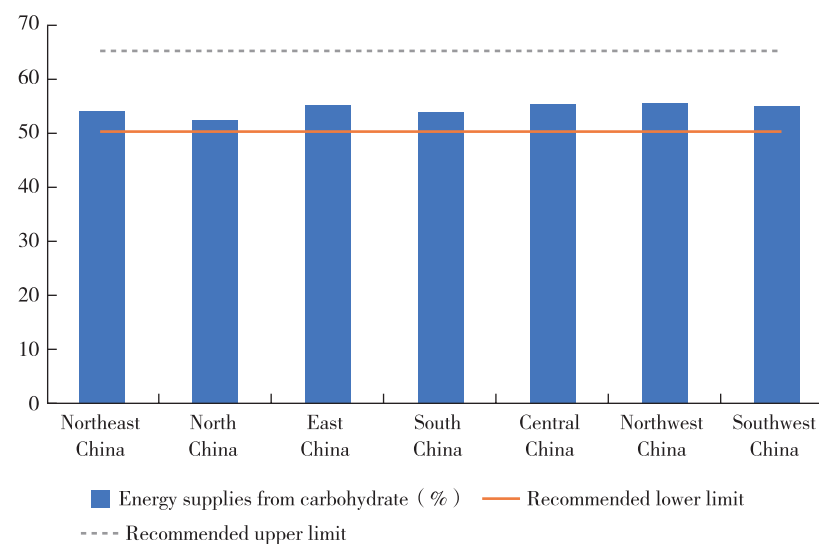


Figure 2.12 Regional comparison of energy supply ratios of fat (percentage) and recommended intake levels



Source: China Nutrition and Health Surveillance (2015)

Figure 2.13 Regional comparison of carbohydrate energy supply ratios (percentage) and recommended intake levels



Source: China Nutrition and Health Surveillance (2015)

(3) Vitamin A and dietary fiber intake

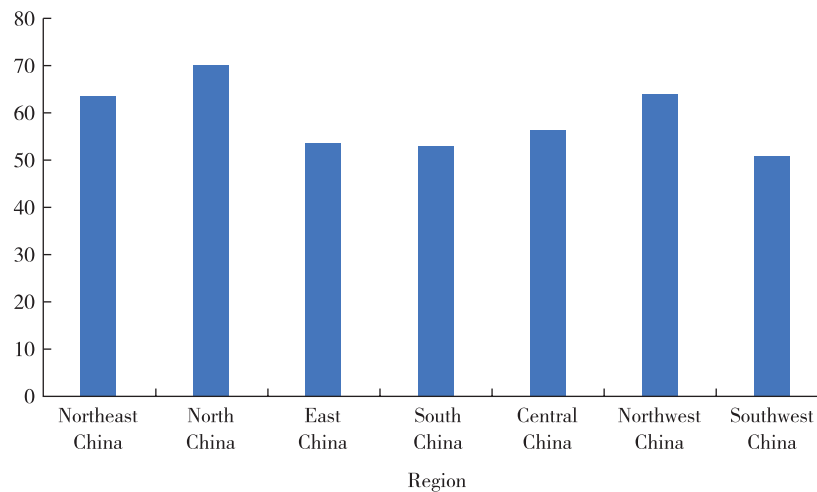
Considering the severity of micronutrient and other dietary nutrient deficiencies and potential sources for supplementation, this study analyzed the dietary vitamin A and fiber intake of residents in different regions. This section shows the proportion of nutrients that falls below the recommended daily intake of dietary fiber and vitamin A based on the recommended intake values published in Chinese Dietary Reference (2013 edition). The calculation method is the same as in the (1) Energy and Protein Intake Assessment section. The specific characteristics are as follows.

The distribution of dietary fiber intake reveals that more than half of the residents across all regions are at risk of consuming an inadequate amount of dietary fiber, with North, Northwest, and Northeast China showing the more severe underconsumption (Figure 2.14).

The distribution of vitamin A intake shows that residents across all regions are at risk of consuming an inadequate amount of vitamin A, with more than 75 percent of residents in Northwest, Northeast, and North China facing the risk of inadequate vitamin A intake (Figure 2.15).

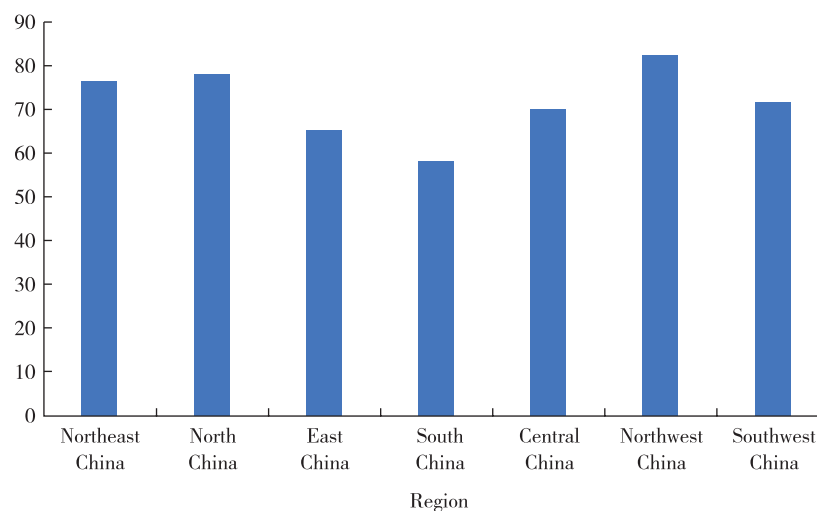


Figure 2.14 Dietary fiber intake below estimated average requirement by region (percentage)



Source: China Nutrition and Health Surveillance (2015)

Figure 2.15 Vitamin A intake below the estimated average requirement by region (percentage)



Source: China Nutrition and Health Surveillance (2015)

2.5 Conclusions and Recommendations

2.5.1 Research Conclusions

First, this study combined different dietary patterns in the domestic and international literature and reviewed the effects of current dietary imbalance on chronic diseases. Healthy dietary patterns were classified in different countries and regions in different patterns, including the DASH diet, the Mediterranean diet, and the traditional Japanese diet. These healthy dietary patterns can prevent many chronic diseases by controlling blood pressure, reducing the risk of death from cardiovascular diseases, preventing diabetes, and reducing incidences

of cancer.

Compared with healthy Western diets, the traditional Chinese diet is a lighter diet that is typified by a higher degree of food diversity, an adequate consumption of fresh vegetables, and a greater intake of aquatic products and soybean products. However, with economic development and lifestyle changes, the dietary structure of the population has gradually shifted toward a high-fat and low-fiber diet, leading to increasing incidences of nutrition-related chronic diseases. Dietary imbalance has become increasingly serious, with an excessive intake of animal-based foods, particularly meat; high levels of cooking oil and salt intake leading to overweight and obesity; and a rising prevalence



of diet-related chronic diseases such as hypertension and diabetes. An unreasonable dietary structure also results in an inadequate intake of micronutrients, which in turn increases the risk of micronutrient deficiencies, particularly in vitamin A, iron, and zinc.

Second, an analysis and evaluation of the current status of the dietary structure of residents in the different regions of China found that residents face a common problem of serious deficiencies in the intake of foods such as fruits and dairy products. However, there are significant regional differences in the intake of foods such as cereals, potatoes, vegetables, animal-based foods, soybeans, and nuts.

Common problems include an inadequate intake of fruits, milk and dairy products. Among these, inadequate fruit intake is not mainly due to dietary preferences but to low affordability and poor accessibility—a sufficient supply would effectively increase residents' fruit intake. At the same time, the recommended intake of fruits in the dietary guidelines is not reasonable. Consideration should be given to setting the total daily recommended intake range of vegetables and fruits and the minimum recommended value of vegetables to encourage residents with insufficient access to fruits to increase their vegetable intake to avoid micronutrient deficiencies. The insufficient intake of milk and dairy products is due to the fact that Chinese residents have not formed a habit of consuming milk and dairy products, and there may be some groups of people whose calcium intake levels are insufficient; therefore, we should focus on the consumption needs of special groups such as children and the elderly.

In addition, there are regional differences in dietary problems, and targeted dietary guidelines are required. North, Northeast, and Northwest China should pay more attention to the problem of insufficient dietary fiber and vitamin A intake and focus on ensuring the supply and affordability of food. South China should pay attention to appropriately reducing the intake of animal-based food and reasonably increasing the intake of beans, soy products, and vegetables. Southwest China should focus on more diversified food intake and increase the intake of coarse grains. East and Central China residents' diets could be considered relatively reasonable, but residents still need to increase their intake of vegetables and reduce their intake of refined grains.

2.5.2 Policy Recommendations

Based on a systematic analysis of the common and characteristic problems of food and nutrient intake of residents in China's seven administrative regions, we suggest the development of targeted dietary guidelines for residents in different regions and provide corresponding work program guidance for health departments in the different regions. The specific policy recommendations are as follows.

It is necessary to guide Chinese residents to consume a reasonable amount of whole grains, fruits, and legumes and reduce their consumption of refined grains and red meat through policy guidance and economic incentives.

More research on the dietary structure and nutritional health of the Chinese population could contribute to a timely improvement and update to dietary guidelines based on changes in the dietary structure of Chinese residents and the problems and challenges they face. Dietary Guidelines for Chinese Residents should be promoted to increase residents' awareness of nutritional health.

Each region should develop strong and regionally specific dietary guidelines and recommendations based on local characteristics.

Hidden hunger caused by an insufficient intake of micronutrients should be addressed by providing multiple food substitution options to improve dietary conditions. Effective scientific interventions are required to improve and address specific issues of micronutrient deficiencies in different regions, such as increasing the intake of food rich in nutrients, fortifying foods, and using nutrient supplements.

References

- Adamsson V, Reumark A, Cederholm T, et al. What is a healthy Nordic diet? Foods and nutrients in the NORDIET study[J]. *Food & nutrition research*, 2012, 56(1): 18189.
- Allen, L.H., 2003. Interventions for micronutrient deficiency control in developing countries: past, present and future. *Journal of Nutrition* 3875S. <https://doi.org/doi:10.1038/sj.ijo.0802401>
- Appel L J, Moore T J, Obarzanek E, et al. A clinical trial of



- the effects of dietary patterns on blood pressure[J]. *New England journal of medicine*, 1997, 336(16): 1117-1124.
- Aune D, Ursin G, Veier D MB (2009) Meat consumption and the risk of type 2 diabetes: a systematic review and meta-analysis of cohort studies. *Diabetologia* 52:2277-2287. <https://doi.org/10.1007/s00125-009-1481-x>
- Azeem S, Gillani SW, Siddiqui A, et al (2015) Diet and Colorectal Cancer Risk in Asia - a Systematic Review. *Asian Pacific Journal of Cancer Prevention* 16:5389-5396. <https://doi.org/10.7314/APJCP.2015.16.13.5389>
- Bach-Faig A, Berry E M, Lairon D, et al. Mediterranean diet pyramid today. Science and cultural updates[J]. *Public health nutrition*, 2011, 14(12A): 2274-2284.
- Baltussen, R., Knai, C., Sharan, M., 2004. Iron Fortification and Iron Supplementation are Cost-Effective Interventions to Reduce Iron Deficiency in Four Subregions of the World. *The Journal of Nutrition*.
- Cai-Jin Y, Jing-Ying S, Gang-Xi L. Meta-analysis of zinc deficiency and its influence factors in children under 14-year-old in china[J]. *J Fam Med*, 2021, 8(5): 1257.
- Campbell, A.P. DASH eating plan: An eating pattern for diabetes management. *Diabetes Spectr*. 2017, 30, 76-81.
- Cena H, Calder P C. Defining a healthy diet: evidence for the role of contemporary dietary patterns in health and disease[J]. *Nutrients*, 2020, 12(2): 334.
- Climate Change Committee of the Third National Climate Change Assessment Report. (2015). Third National Climate Change Assessment Report. Science Press. (in Chinese)
- Copenhagen Consensus Center, 2004. . Copenhagen consensus-vision and facts. URL <https://www.copenhagenconsensus.com/> (accessed 2.28.05).
- Dai, S., Yang, F., Hu, Y., Xiao, X. (2021). Research progress on the relationship between different dietary patterns and common chronic non-communicable diseases. *Chinese Journal of Epidemiology*, 42(8), 1509-1517. (in Chinese)
- Du, S.; Mroz, T.A.; Zhai, F.; Popkin, B.M. Rapid income growth adversely affects diet quality in china—Particularly for the poor! *Soc. Sci. Med*. 2004, 59, 1505-1515.
- Du, S.F.; Wang, H.J.; Zhang, B.; Zhai, F.Y.; Popkin, B.M. China in the period of transition from scarcity and extensive undernutrition to emerging nutrition-related non-communicable diseases, 1949-1992. *Obes. Rev*. 2014, 15, 8-15.
- Estruch R, Ros E, Salas-Salvadó J, et al. Primary prevention of cardiovascular disease with a Mediterranean diet[J]. *New England Journal of Medicine*, 2013, 368(14): 1279-1290.
- Guallar-Castillón P, Rodríguez-Artalejo F, Tormo M J, et al. Major dietary patterns and risk of coronary heart disease in middle-aged persons from a Mediterranean country: the EPIC-Spain cohort study[J]. *Nutrition, Metabolism and Cardiovascular Diseases*, 2012, 22(3): 192-199.
- Kurotani K, Budhathoki S, Joshi AM, et al (2010) Dietary patterns and colorectal cancer in a Japanese population: the Fukuoka Colorectal Cancer Study. *British journal of nutrition* 104:1703-1711. <https://doi.org/10.1017/S0007114510002606>.
- Lammi C, Aiello G, Boschini G, Arnoldi A (2019) Multifunctional peptides for the prevention of cardiovascular disease: A new concept in the area of bioactive food-derived peptides. *Journal of Functional Foods* 55:135-145. <https://doi.org/10.1016/j.jff.2019.02.016>.
- Lee, K.W., Cho, M.S., 2014. The Traditional Korean Dietary Pattern Is Associated with Decreased Risk of Metabolic Syndrome: Findings from the Korean National Health and Nutrition Examination Survey, 1998-2009. *Journal of Medicinal Food* 17, 43-56. <https://doi.org/10.1089/jmf.2013.3049>
- Li, Q., Wang, Y., Luo, X., Xu, T., Fang, F., & Wang, F. (2017). Research progress on soybean oligosaccharides and their hypolipidemic effects. *Journal of Nuclear Agriculture Science*, 31(9), 1788-1793. (in Chinese)
- Luo, X., Fang, F., Wang, F. (2016). Research on the effects of sprouting on nutrition and anti-nutritional factors in soybeans. *Journal of Nuclear Agriculture Science*, 30(4), 764-769. (in Chinese)
- Ma, G., Jin, Y., Li, Y., Zhai, F., Kok, F.J., Jacobsen, E., Yang, X., 2008. Iron and zinc deficiencies in China: what is a feasible and cost-effective strategy? *Public Health Nutrition* 11, 632-638. <https://doi.org/10.1017/S1368980007001085>
- Matsuyama S, Sawada N, Tomata Y, et al (2021) Association between adherence to the Japanese



- diet and all-cause and cause-specific mortality: the Japan Public Health Center-based Prospective Study. *Eur J Nutr* 60:1327-1336. <https://doi.org/10.1007/s00394-020-02330-0>
- McCann JC, Ames BN, 2007. An overview of evidence for a causal relation between iron deficiency during development and deficits in cognitive or behavioral function. *The American journal of clinical nutrition* 85. <https://doi.org/10.1093/ajcn/85.4.931>
- Mizoue T, Yamaji T, Tabata S, et al (2005) Dietary patterns and colorectal adenomas in Japanese men: the Self-Defense Forces Health Study. *American journal of epidemiology* 161:338-345. <https://doi.org/10.1093/aje/kwi049>
- Morimoto A, Ohno Y, Tatsumi Y, et al (2012) Effects of healthy dietary pattern and other lifestyle factors on incidence of diabetes in a rural Japanese population. *Asia Pacific Journal of Clinical Nutrition* 21:601-608.
- Mukherjee, P.K., Ilangantileke, S., 2002. Dietary intervention with orange fleshed sweetpotato (*Ipomoea batatas* (L.) Lam.) to alleviate vitamin A deficiency in South and West Asia. *Acta Horticulturae* 205-210. <https://doi.org/10.17660/ActaHortic.2002.583.23>
- Ni, Y., Yang, X., Du, J., et al. (2018). Meta-analysis of the relationship between soy product intake and the risk of gastric cancer. *Journal of Shandong University (Health Sciences)*, 56(10), 93-102. (in Chinese)
- Norat T, Riboli E (2009) Meat Consumption and Colorectal Cancer: A Review of Epidemiologic Evidence. *Nutrition Reviews* 59:37-47. <https://doi.org/10.1111/j.1753-4887.2001.tb06974.x>
- Ojagbemi A, Okekunle AP, Olowoyo P, et al (2021) Dietary intakes of green leafy vegetables and incidence of cardiovascular diseases. *CVJA* 32:43-51. <https://doi.org/10.5830/CVJA-2021-017>
- Open Source Geospatial Foundation Chinese Chapter. (2016). Climate Characteristics of Southern China. Retrieved from: <https://www.osgeo.cn/post/2a7f1>. (in Chinese)
- Panagiotakos D B, Pitsavos C, Chrysoshoou C, et al. The epidemiology of Type 2 diabetes mellitus in Greek adults: the ATTICA study[J]. *Diabetic medicine*, 2005, 22(11): 1581-1588.
- Pierce, G.N., Izumi, T., Rupp, H., Grynberg, A. (Eds.), 1998. *Molecular and Cellular Effects of Nutrition on Disease Processes*. Springer US, Boston, MA. <https://doi.org/10.1007/978-1-4615-5763-0>
- Rimm, E. B., Appel, L. J., Chiuve, S. E., Djoussé, L., Engler, M. B., Kris-Etherton, P. M., ... & Lichtenstein, A. H. (2018). Seafood long-chain n-3 polyunsaturated fatty acids and cardiovascular disease: a science advisory from the American Heart Association. *Circulation*, 138(1), e35-e47.
- Sadakane A, Tsutsumi A, Gotoh T, et al (2008) Dietary patterns and levels of blood pressure and serum lipids in a Japanese population. *Journal of epidemiology* 18:58-67
- Sala-Vila A, Fleming J, Kris-Etherton P, Ros E (2022) Impact of α -Linolenic Acid, the Vegetable ω -3 Fatty Acid, on Cardiovascular Disease and Cognition. *Advances in Nutrition* 13:1584-1602. <https://doi.org/10.1093/advances/nmac016>
- Siervo M, Lara J, Chowdhury S, et al. Effects of the Dietary Approach to Stop Hypertension (DASH) diet on cardiovascular risk factors: a systematic review and meta-analysis[J]. *British Journal of Nutrition*, 2015, 113(1): 1-15.
- Sommer, A., Jr, W.K., Olson, J.A., Ross, A.C., 1998. *Vitamin A deficiency: health survival and vision*. New York New York Oxford University Press 404-405.
- Toh, D.W.K., Koh, E.S., Kim, J.E., 2020. Incorporating healthy dietary changes in addition to an increase in fruit and vegetable intake further improves the status of cardiovascular disease risk factors: A systematic review, meta-regression, and meta-analysis of randomized controlled trials. *Nutrition Reviews* 78, 532-545. <https://doi.org/10.1093/nutrit/nuz104>
- West, K.P., 2005. *Vitamin A: Deficiency and Interventions*. Encyclopedia of Human Nutrition.
- Xie H., Zhang L., Jiang W., & Cheng X.-L. (2006). Resource and Environmental Basis for Development in Central China at the Beginning of the 21st Century (Doctoral dissertation). (in Chinese)
- Yang L. The effect of Western diet culture on Chinese diet culture[C]//International Conference on Education, Language, Art and Intercultural Communication (ICELAIC-14). Atlantis Press, 2014: 671-674.
- Zhai, F.Y.; Du, S.F.; Wang, Z.H.; Zhang, J.G.; Du, W.W.; Popkin, B.M. Dynamics of the Chinese diet and the



role of urbanicity, 1991–2011. *Obes. Rev.* 2014, 15, 16–26.

Zhang, J., Wang, C., Li, L., Man, Q., Song, P., Meng, L., Du, Z.-Y., Frøyland, L., 2010. Inclusion of Atlantic salmon in the Chinese diet reduces cardiovascular disease risk markers in dyslipidemic adult men. *Nutr Res* 30, 447–454. <https://doi.org/10.1016/j.nutres.2010.06.010>

Zhong W, Zhang Y, Wu Z, et al (2018) Health risk assessment of heavy metals in freshwater fish in the central and eastern North China. *Ecotoxicology and Environmental Safety* 157:343–349. <https://doi.org/10.1016/j.ecoenv.2018.03.048>

Zhong, X., Zhang, C. (2012). Meta-analysis of the relationship between soy food intake and breast cancer risk. *Chinese Journal of Health Research*, 41(4), 670–676. (in Chinese)







Chapter 3

Sustainable Healthy Diets in China

Yumei Zhang^{1,2}, Li Xue^{1,2}, Shenggen Fan^{1,2}, Kevin Z. Chen^{3,4}, Xinyue Ding^{1,2}, Xiaolong Feng^{1,2}, Ting Meng^{1,2}, Zhiming Yuan^{1,2}, and Xiangyang Zhang^{1,2}

1. Academy of Global Food Economics and Policy,

2. College of Economics and Management, China Agricultural University

3. China Academy for Rural Development, Zhejiang University

4. International Food Policy Research Institute



Key Findings

- With the improvement of living standards, dietary imbalances is becoming increasingly severe. This poses serious challenges to the health of China's residents and exerts great pressures on the resources and environment, making agri-food systems unsustainable. The per capita carbon emissions, water footprint (WF), nitrogen footprint (NF), and phosphorus footprint (PF) related to food consumption in China in 2020 were 0.83 tons, 878 cubic meters, 13.2 kilograms, and 1.5 kilograms, respectively. It is projected that By 2030, total carbon emissions associated with food consumption will increase by 8 percent from 1.18 billion tons in 2020 to 1.28 billion tons.
- The recommended dietary pattern proposed by Dietary Guideline for Chinese Residents (2022) is far from sustainable and healthy mainly due to the excessive consumption of dairy products, which leads to a significant increase in carbon emissions and largely offsets the positive environmental effects resulting from reducing grain and meat consumption. Compared to the baseline scenario, while following the dietary guideline can reduce carbon emissions by 10 percent, water consumption by 4.8 percent, and NF and PF by

12.8 percent and 20.5 percent, respectively, by 2030, it is still far from achieving the "Carbon Peaking and Carbon Neutrality Goals."

- To safeguard the nutrition of residents while minimizing environmental impacts, various strategies can be adopted, such as strategies such as reducing refined grain consumption according to the dietary guidelines, increasing fruit consumption, substituting meat with soybean, and adjusting the structure of meat consumption should be implemented. Under this combined scenario, carbon emissions related to food consumption can be reduced by 19.4 percent (250 million tons) compared to the baseline scenario. The most significant reduction was found in Southwest China, with a decrease of 30.7 percent. Water consumption can be reduced by 6.0 percent, with reductions of more than 11 percent in North and Northeast China; nitrogen and phosphorus emissions footprints can be reduced by 21.94 percent and 16.3 percent, respectively.



Policy Recommendations

- Optimizing dietary structure is essential to ensure human well-being, protect the environment, and achieve carbon neutrality. A cross-departmental coordination mechanism to jointly develop “sustainable and healthy diets” guidances at the national and regional levels is badly needed, which would actively guide food consumption on a path toward sustainability and health.
- To promote sustainable and healthy dietary patterns, China needs to adjust the food supply structure and increase production support for foods such as beans, fruits, poultry, and aquatic products. This adjustment

will enhance the diversity of the food supply, promote sustainability, and improve food accessibility.

- In addition to optimizing the food consumption structure, accelerating the promotion of the transition to green and low-carbon food production, distribution, and household consumption is necessary. Shortening food transportation distances and reducing food losses and energy use would also contribute to reducing carbon, nitrogen, and phosphorus emissions, foodprints, and water use.



3.1 Introduction

To meet the growing demand for diversified food, especially animal-based food, Chinese agriculture has operated with high input and high output. This has resulted in great resource and environmental burdens. Achieving a sustainable transformation of agri-food systems requires changing not only agricultural practices but also dietary patterns. However, most studies mainly focus on dietary nutrition and health, while few studies explore the environmental impacts of diet. It has been reported that following Chinese Dietary Guideline (2016), the EAT-Lancet diet, the Mediterranean diet, and meatless diet can reduce significant carbon emissions (Academy of Global Food Economics and Policy of China Agricultural University et al. 2021; Sheng et al. 2021). However, following the 2016 Chinese Dietary Guidelines could lead to an increase in greenhouse gas emissions, water consumption, and land use (He et al. 2019). Some studies have explored dietary structures that can improve nutrition while being environmentally friendly (Wu et al. 2022). Most studies have focused on the national level, while little attention has been paid to dietary and related environmental impacts at the regional level.

Therefore, this chapter aims to explore differences in dietary patterns and related environmental impacts across different regions by considering local food resources and dietary combinations with minimal environmental impacts to promote sustainable dietary patterns. First, we will evaluate differences in the current environmental impacts of food consumption in various regions and then simulate and compare the environmental impacts of different food consumption choices while ensuring the nutritional health of residents. Ultimately, this study will facilitate policy recommendations to promote China's sustainable and healthy dietary transformation.

3.2 The Environmental Impact of Food Consumption in Different Regions of China

Based on the food consumption patterns in different regions and the environmental emission factors of various foods, we calculated the resource and environmental impacts of food consumption across different regions in China. The carbon emission factors

of various food types at different stages along the food supply chain were calculated based on the China Products Carbon Footprint Factors Database (2022), the Barilla Center for Food & Nutrition Foundation database, and other relevant reports (e.g., Cai et al. 2022; Poore and Nemecek 2018; Song et al. 2015; Xue et al. 2021). The water footprint (WF) factors of different food types mainly came from the Water Footprint Network database, with green, blue, and gray WF parameters selected for each plant-based and animal-based product. The NF and PF In terms of the NF and PF coefficients, we referred to Xue and colleagues (2021). The environmental impacts of diet in different regions are presented below.

3.2.1 The Carbon Footprint (CF) of Food Consumption

In 2020, the total CF of food consumption in China was nearly 1180 million tons, accounting for 9.0 percent of the total national carbon emissions. The East region had the largest CF from food consumption, reaching 270 million tons, which accounted for 23.0 percent of the national total. The second largest CF from food consumption was in the Central region (220 million tons), with a share of 18.3 percent. Meanwhile, the Northwest and Northeast regions had the lowest CFs related to food consumption, with 90 million tons, accounting for 7.7 percent.

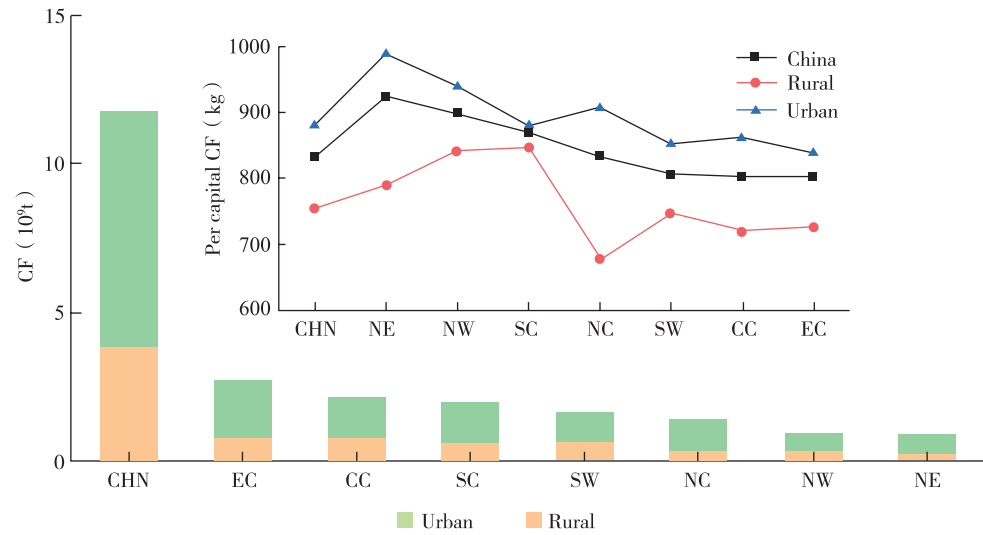
In 2020, the CF of food consumption was 834 kilograms per capita, see Figure 3.1. The Northeast region had the highest per capita CF, at 925 kilograms, which was more than 10 percent higher than the national average. The East region had the lowest per capita CF, at 802.8 kilograms, which was 86.8 percent of the Northeast region's emissions. There was a significant difference between urban and rural residents. The per capita CFs for urban and rural residents were 879 kilograms and 753 kilograms, respectively, with urban emissions' being 16.7 percent higher than that of rural areas. The largest per capita CF for urban residents was in the Northeast region, at 990 kilograms, which was 5 to 18 percent higher than that of urban residents in other regions. The rural residents in South China had the largest per capita CF, reaching 846 kilograms.

In terms of CF sources, meat was dominant in total carbon emissions, with a share of nearly 48.3 percent,

followed by grains, which accounted for more than 27.0 percent (Figure 3.2). In each region, meat consumption had the highest CF, accounting for more than 40 percent, particularly in the Northwest region, where it exceeded

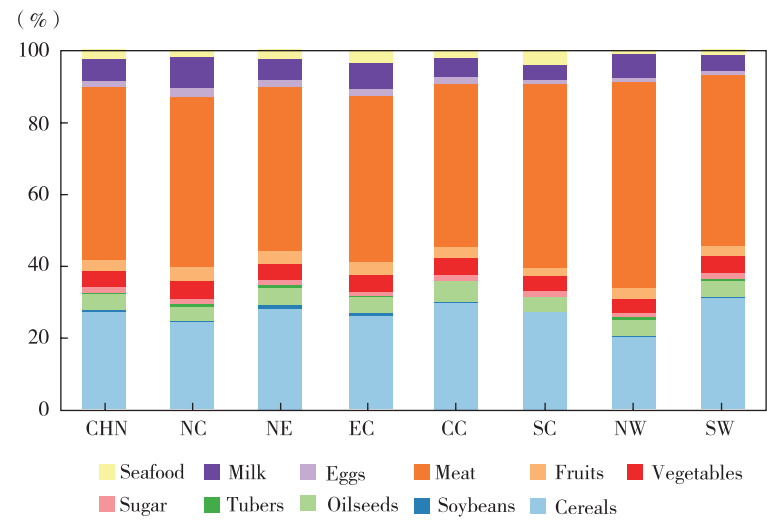
57 percent. Cereals were the second largest source of CF in each region, accounting for 20 to 31 percent in total emissions. The CF of other food types were relatively small.

Figure 3.1 Total and per capita carbon emissions of food consumption by region in China



Source: Authors' calculation.
Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest.

Figure 3.2 Carbon emission structure of food consumption by region in China



Source: Authors' calculation
Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest.

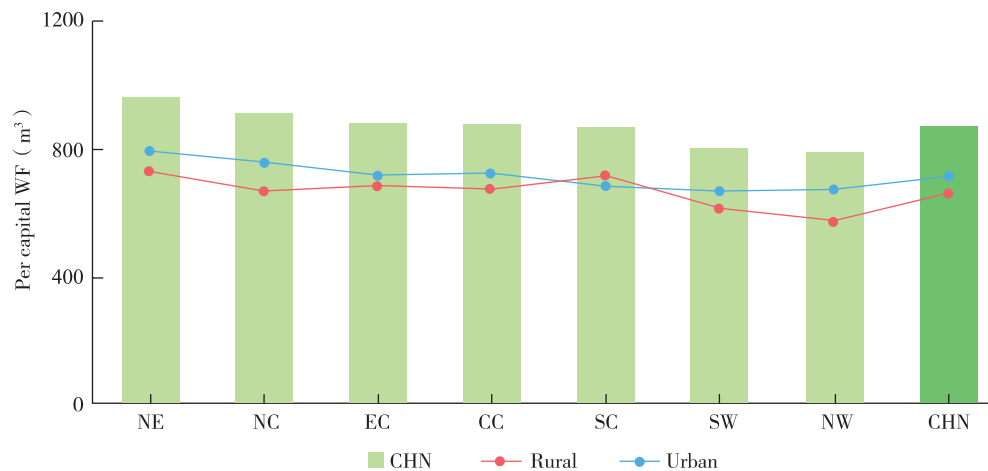
3.2.2 The Water Footprint of Food Consumption

In 2020, the WF was 878 cubic meters per capita. The Northeast region had the largest per capita WF of food consumption, reaching 971 cubic meters, which was 10 percent higher than the national average (Figure 3.3).

The Northwest region had the lowest per capita WF, at 801 cubic meters, which was 82 percent of the Northeast region's level. There was a certain gap in per capita WF of food consumption in urban and rural areas, with 900 cubic meters and 839 cubic meters, respectively. The WF in urban areas was 7 percent higher than that in rural areas.



Figure 3.3 Per capita food consumption and water footprint by region in China



Source: Authors' calculation

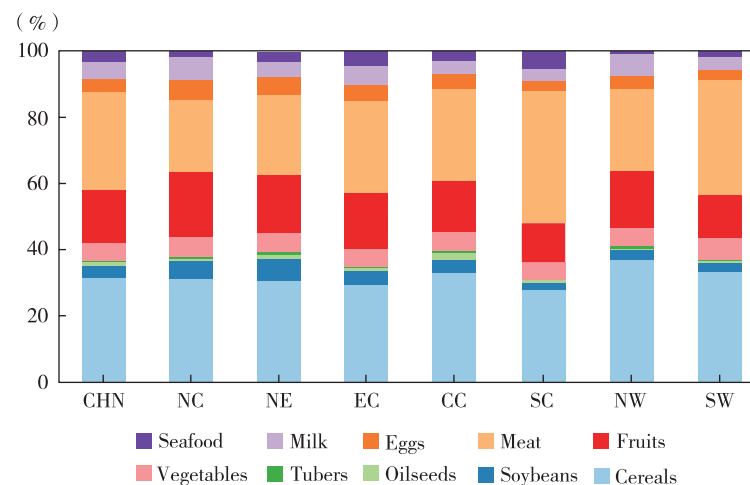
Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest.

For urban residents, the per capita WF was highest in the Northeast region, at 957 cubic meters, while the Southwest region had the lowest per capita WF, reaching almost 839 cubic meters. For rural residents, the South China region had the highest per capita WF, reaching 904 cubic meters, while the Northwest region had the lowest per capita WF at 725 cubic meters.

In terms of WF sources, cereals were dominant in total water consumption, with a share of 31 percent, followed by meat, which accounted for 29 percent

(Figure 3.4). For different regions, cereals consumption had the largest WF in the East, North, Northeast, Central, and Northwest regions, accounting for 30 to 37 percent, followed by meat, accounting for 21 to 27 percent. In the South and Southwest regions, meat consumption had the largest WF, accounting for 34 to 39 percent, followed by cereals, with shares of 28 to 33 percent. Fruits were the third-largest contributor to WF in each region, accounting for 12 to 20 percent WF was from fruits in each region, accounting for 12 to 20 percent.

Figure 3.4 Structure of water footprint by region in China



Source: Authors' calculation

Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest.

3.2.3 The Nitrogen Footprint of Food Consumption

In 2020, the NF from food consumption was 13.2 kilograms per capita, see Figure 3.5. The Northwest

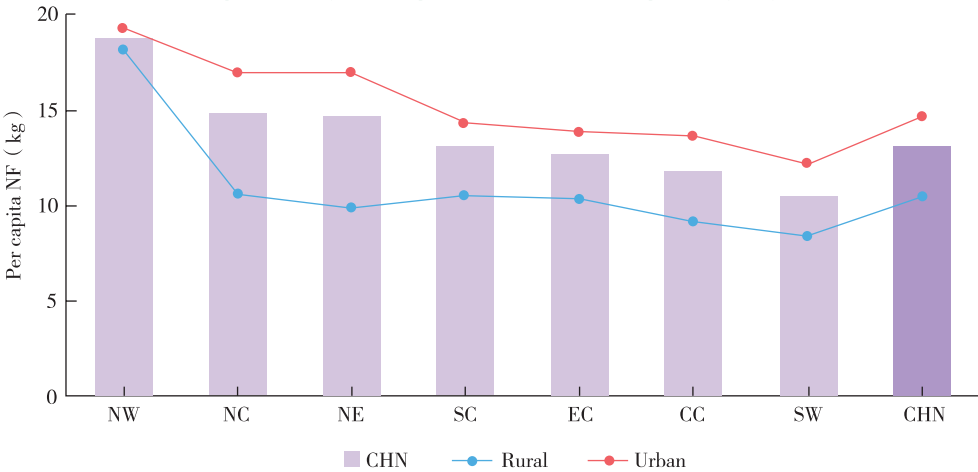
region had the largest per capita NF from food consumption, reaching almost 18.8 kilograms, which was 43 percent higher than the national average. The NF of food consumption in the Northeast, North, East, and South China regions exceeded 12 kilograms per capita,

while the Southwest region had the lowest per capita NF, slightly more than 10 kilograms. For urban residents, the Northwest region had the largest per capita NF from food consumption, exceeding 19 kilograms, which was 58 percent higher than the lowest per capita NF in the Southwest region. For rural residents, the Northwest region still had the highest per capita NF, exceeding 18 kilograms, while the Southwest region had the lowest per capita NF, reaching almost 8.4 kilograms.

In terms of NF sources, meat was the largest contributor, accounting for more than 66 percent of

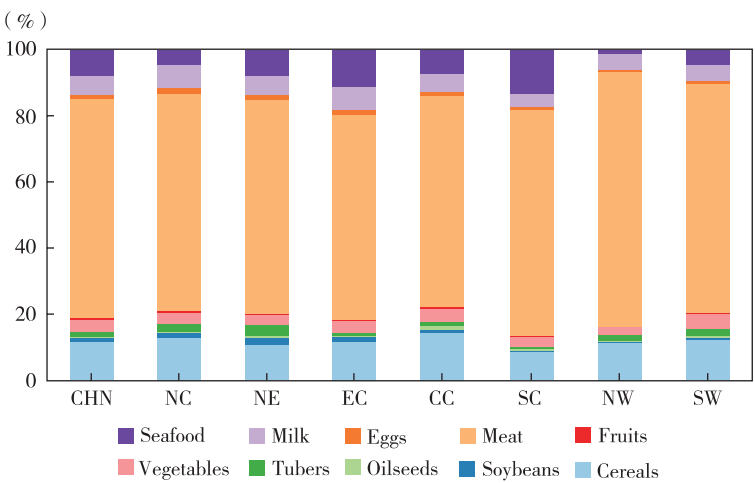
total nitrogen emissions, followed by cereals, which accounted for 12 percent (Figure 3.6). Aquatic products were the third-largest source, accounting for 8 percent. Meat consumption had the largest NF in each region, accounting for 60 to 80 percent, particularly in the Northwest region, where it exceeded 76 percent. In the South China region, aquatic products were the second largest source of NF, accounting for 13.4 percent, while in other regions, cereals were the second-largest source, accounting for 11 to 12 percent. The NF from other food types were relatively low.

Figure 3.5 Per capita nitrogen footprint of food consumption by region in China



Source: Authors' calculation
Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest.

Figure 3.6 Nitrogen footprint sources of food consumption by region in China



Source: Authors' calculation
Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest

3.2.4 The Phosphorus Footprint of Food Consumption

In 2020, the PF from food consumption was 1.5 kilograms

per capita. The Northwest region had the largest per capita PF from food consumption, reaching almost 2 kilograms, while the Southwest region had the lowest per capita PF at 1.2 kilograms, see Figure 3.7. For urban

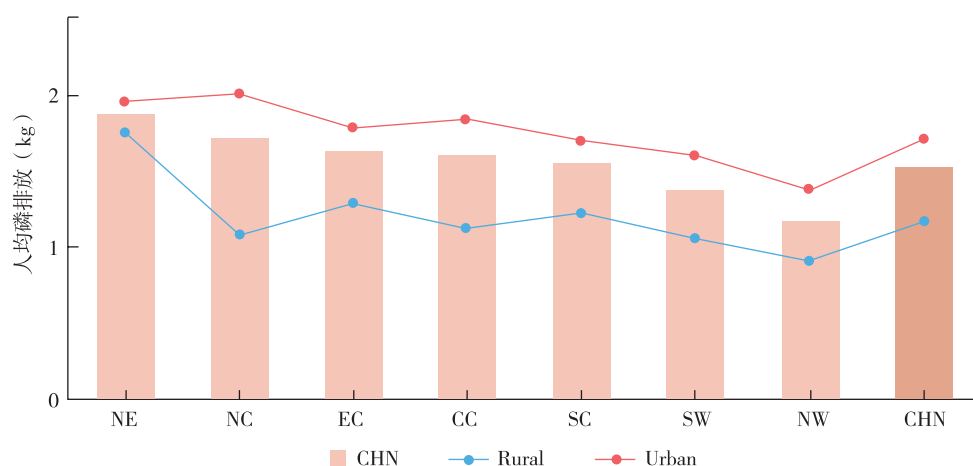


residents, the per capita PF from food consumption in the South, Northwest, Northeast, East, and North regions were similar, reaching 2 kilograms per capita, while the Southwest region had the lowest per capita PF at 1.4 kilograms. For rural residents, the Northwest region had the highest per capita PF at 1.8 kilograms, while the Southwest region had the lowest per capita PF at less than 1 kilogram.

In terms of PF sources, meat was the largest source, accounting for 58.5 percent of total phosphorus emissions, followed by aquatic products, which

accounted for more than 19 percent (Figure 3.8). Cereals were the third-largest source, with a share of 7.2 percent. PFs from meat were dominant in all regions, accounting for 52 to 75 percent, particularly in the Northwest region, where the PF exceeded 74 percent. Except in the Northwest region, aquatic products were the second largest source of PF, accounting for between 11 and 30 percent. In the Northwest region, cereals were the second largest source, accounting for nearly 10 percent. The PFs of other food types were relatively low.

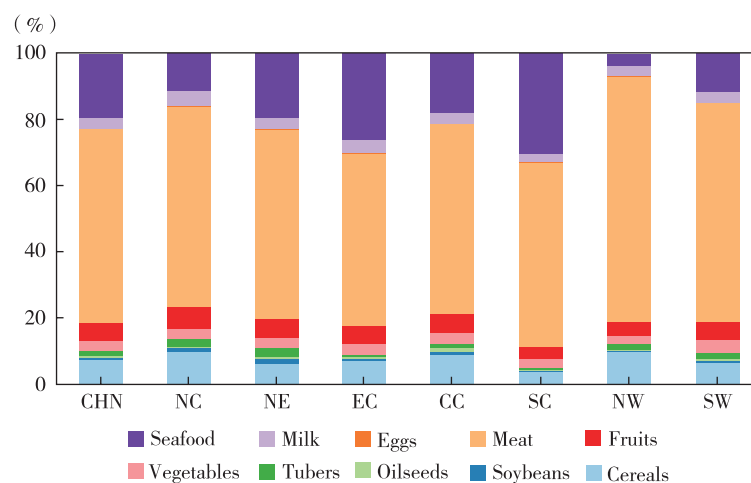
Figure 3.7 Per capita phosphorus footprint from food consumption by region in China



Source: Authors' calculation

Note: PF = phosphorus footprint. NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest

Figure 3.8 Structure of phosphorus footprint from food consumption by region in China



Source: Althours' calculation

Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest



3.3 Simulation and Optimization of China's Sustainable and Healthy Dietary Patterns

3.3.1 Modeling

This study utilizes the China Agricultural University Agri-Food System model to evaluate the environmental impacts of food consumption in different regions. The model covers various aspects of agriculture, food, economy, nutrition, and environment. It aims to provide technical support for studying the major interdisciplinary issues in the transformation of agri-food systems, as described in detail in China and Global Food Policy Report 2022 (AGFEP, et al., 2022). In particular, this chapter China Agricultural Spatial Equilibrium Model and the environmental module to simulate the environmental impacts of dietary change. The China Agricultural Spatial Equilibrium Model is a partial equilibrium model for agricultural products at the provincial level with a base year of 2020, covering 31 provinces, municipalities, and autonomous regions. This model also considers differences in food consumption in different regions and covers 58 agricultural products, including 15 types of grains (rice, wheat, corn, soybeans, mung beans, red beans, other beans, potatoes, other potatoes, millet, sorghum, barley, oats, buckwheat, and other cereals), cotton, tobacco, 2 types of sugar crops (sugarcane and sugar beet), 4 types of oilseeds (rapeseed, peanuts, sesame, and camellia seed), vegetables, 11 types of fruits (bananas, apples, citrus, pears, grapes, pineapples, dates, persimmons, watermelons, muskmelons, and other fruits), 4 types of forest products/dried fruits (chestnuts, hazelnuts, pine nuts, and walnuts), 6 types of livestock products (pork, beef, lamb, poultry, eggs, and milk), 5 aquatic products (fish, shrimp, shellfish, algae, and other fish), and 8 types of processed agricultural products (soybean meal, soybean oil, rapeseed meal, rapeseed oil, peanut meal, peanut oil, sugar, and camellia oil). The environmental module contains indicators for CF, WF, NF, and PF. It enables the evaluation of the environmental impacts of food consumption from multiple dimensions. The coefficients of different environmental impacts are consistent with those in section 3.2.

3.3.2 Scenario Settings

First, wide space here. the baseline scenario assumptions. Based on the assumptions on population, urbanization rates, gross domestic product (GDP) growth, and technological progress, we simulated and projected the future trends of agricultural production, consumption, trade, and prices in China and various regions under the “business-as-usual” scenario by 2030. We assumed that the future total population reach its peak in 2023 and subsequently decrease, the urbanization rate will gradually increase, and the economy will grow steadily. First, the population in 2020 reported by China's National Bureau of Statistics was used as a basis. The population growth rate was based on the middle scenario growth rate reported for China in 2022 by the United Nations Population Division. It is expected that the total population in China will decline to approximately 1.4 billion people by 2030, with an urbanization rate approaching 70 percent. Due to a lack of projected province-level population, it was assumed that the population distribution structure in each province will remain unchanged. Second, the economic growth rates were referred to the projection results of the World Bank and the Macroeconomic Research Center projection team of the Chinese Academy of Social Sciences and others (2020) during 2021 and 2030. The actual GDP growth rates per province were used as the reference for 2021 and 2022, and the average GDP growth rates per year from 2023 to 2030 were set based on each province's historical GDP growth rate, with a gradual growth rate of 5 to 6 percent per year. Third, the income of urban and rural residents were assumed to continue to grow, and rural residents' incomes grow slightly faster than that of urban residents, which resulted in a narrowing of the income gap between urban and rural areas. Fourth, based on the historical growth rates of crop yields and livestock carcass weights in various provinces, we set the growth rates of various crops yield and livestock carcass weights from technological progress. Finally, we assumed a relatively stable total arable land area.

Second, we developed several scenarios. To explore sustainable healthy dietary patterns when considering current food consumption, food composition, and environmental impacts of different food production



practices, five scenarios were designed. All the scenarios assumed dietary change from 2023 to 2030. Scenario 1 (referred to as the DIET scenario) assumed that both urban and rural residents followed the Dietary Guidelines for Chinese Residents (2022) (hereinafter referred to as “the guidelines”), as listed in Table 3.1. Scenario 2 (fruit scenario [FRTS]) considered the diversity of food consumption, which was mainly based on cereals consumption’s exceeding significantly the recommended amounts listed in the guidelines. This scenario followed the recommended cereals intake level of 250 grams per day by 2030, resulting in the consumption of cereals (rice and wheat) being reduced by 50 million tons. However, fruit consumption falls below minimum recommendation levels, so fruit intake is increased equally by 100 grams per person per day. Scenario 3 (soybean substitution scenario [SSUB]) focused primarily on plant protein, which was considered to replace animal protein, with increased soybean consumption instead of consumption of pork or beef/lamb meat. Under the current insufficient soybean demand coupled with the increase of domestic soybean production, it was assumed that when soybean demand increases by 10 million tons, consumption of pork and beef/lamb would be reduced by 10 million tons based on the soybean protein content and digestion

absorption rate. This is equivalent to an increase of 20 grams per person per day in soybean consumption and a concurrent reduction in meat consumption by the same amount. Scenario 4 (meat restructuring scenario [STRC]) considered the change of meat consumption structure based on different regional characteristics. It was assumed that a reduction in carbon emissions from high-emitting beef/lamb and pork products and an increase in poultry, egg, and aquatic product consumption. The national consumption of pork and beef will be reduced by 30 percent, or 17 million tons, while an equivalent amount of poultry, eggs, and aquatic products will be consumed. Scenario 5 was a combined scenario (COMB) that assumed a reasonable reduction in the consumption of cereals and meat and an increase in the consumption of fruits and soybeans while adjusting the meat consumption structure. This scenario is similar to scenario 3 but added an increase in fruit consumption by 50 million tons, reduced cereals consumption by an equal amount, and replaced 6 million tons of pork, beef, and lamb consumption with 11 million tons of poultry, egg, and aquatic product consumption. Please refer to Table 3.2 for more details about the design of these scenarios.

Table 3.1 Recommended Intake of Various Foods in Dietary Guidelines for Chinese Residents (2022)

Food Category	Recommended Intake Per Capita (grams)
Edible oil	25-30
Milk and dairy products	300-500
Soybean and nut products	25-35
Animal products	120-200
Vegetables	300-500
Fruits	200-350
Cereals	200-300
Potatoes	50-100

Source: Dietary Guidelines for Chinese Residents (2022).



Table 3.2 Simulation Scenario Settings

Scenario Name	Simulation Scenario	Reference for Setting
Diet scenario (DIET)	Set the intake of various products to 91 kilograms per year for cereals, 27 kilograms per year for potatoes, 11 kilograms per year for soybeans, 10 kilograms per year for edible oil, 146 kilograms per year for vegetables, and 100 kilograms per year for fruits; the consumption will consider the edible portion.	Based on recommended intake standards in the guidelines.
Fruit scenario (FRTS)	Reduce the consumption of rice and wheat by 50 million tons and increase fruit consumption by an equivalent amount while keeping other products unchanged; the changes in rice and wheat consumption in various regions are adjusted proportionally according to the local residents' consumption structure.	Cereals consumption and reduction based on recommended standards in the guidelines, and correspondingly increase fruit consumption.
Soybean substitution scenario (SSUB)	Increase soybean consumption by 10 million tons, and reduce the consumption of pork, beef, lamb, and pork products by an equal amount. The proportion of changes in various meat consumption levels in each region will be proportional to the changes in local residents' consumption structure.	The proportion of meat protein that can be replaced by soybean protein based on soybean protein content and the digestion absorption rate, which is approximately 1:1.
Meat restructuring scenario (STRC)	Reduce pork and beef consumption by 30 percent, or 17 million tons, replaced by consumption of an equivalent amount of poultry, eggs, and aquatic products. The consumption of various foods changes in proportion to local food consumption structure.	Reduce red meat consumption, increase white meat consumption, promote health, and reduce environmental impacts.
Combined scenario (COMB)	Increase fruit consumption by 50 million tons; reduce cereals consumption by an equivalent amount; increase soybean consumption by 6 million tons; increase consumption of poultry, eggs, and aquatic products by 11 million tons; and reduce pork, beef, and lamb consumption by a total of 17 million tons.	Combine three scenarios.

Source: Authors' settings.

Note: The data here are recommended intake amounts, and the model estimates food consumption based on the proportion of edible parts of the food.

3.3.3 Environmental Impacts of Food Consumption in Different Regions under the Baseline Scenario

The Baseline scenario provides insight into the future food consumption in different regions and its impact on the environment by analyzing historical trends and provides a reference for the policy simulation scenario. During 2020-2030, the food consumption nationwide and in all regions would be still in transition and keep growing. The direct consumption of cereals shows a decreasing trend, and meat, vegetable and fruit consumption keep growing, but at a slower pace.

In terms of per capita food consumption, it shows a similar trend in each region (Figure 3-9). The per capita consumption of staple grains will decrease by 6.4% in 2030 compared to 2020. Conversely, pork and egg consumption will increase by 10%, and beef and lamb and poultry consumption will grow faster, both exceeding 20%. Milk and aquatic products consumption will increase mostly rapidly by 25%, with an average annual growth rate of 2%. In addition, the consumption of vegetables and fruits will be increased by 11% and 18%, respectively, with an average annual growth rate of 1% and 2%, respectively.

Total food consumption is in line with the per

capita food consumption due to the small change of population. Compared to 2020, the cereals for direct consumption will decrease by 7.3%, while

the consumption of dairy and fish, fruits and meat, vegetables and eggs will increase by 25%, 17% and 15%, 10% and 8%, respectively, by 2030. The potatoes and

Figure 3.9 Projected per capita food consumption by region in China in 2020 and 2030

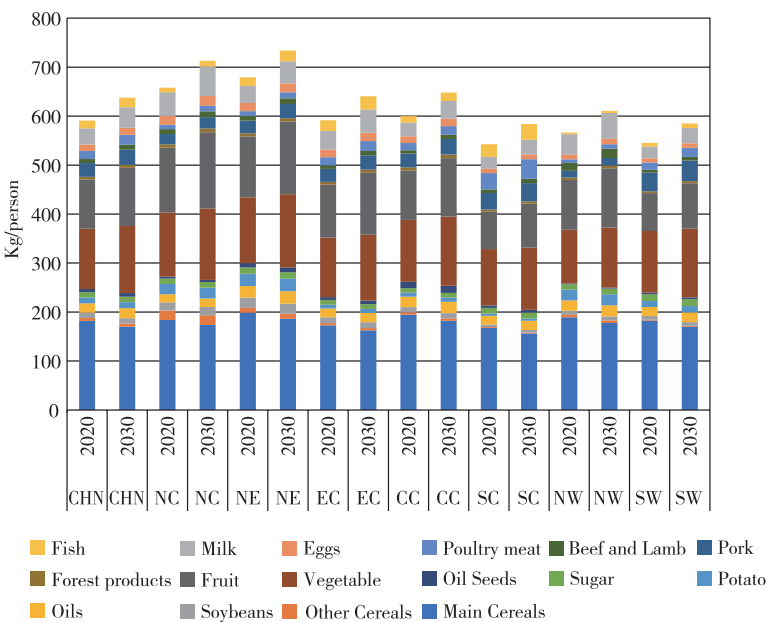
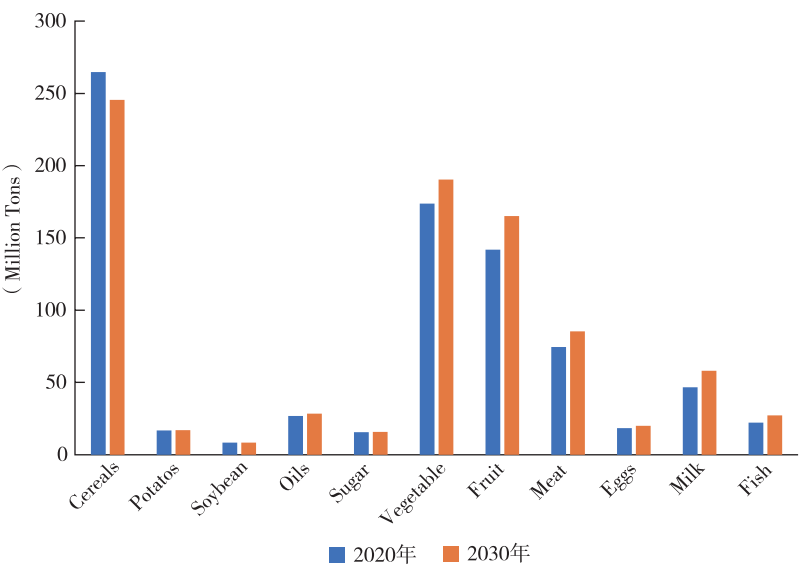


Figure 3.10 Projected national food consumption in China in 2020 and 2030

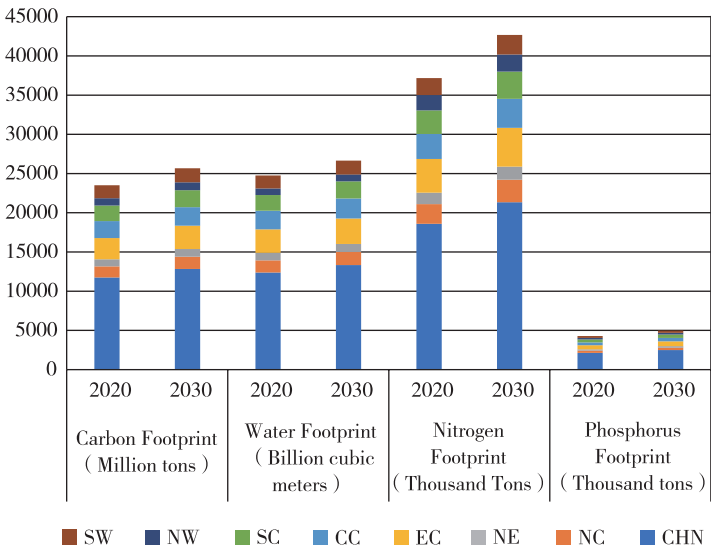


sugar will increase by only 2%, as shown in Figure 3-10.

In 2030, the CF and WF related to national food consumption will reach 1.28 billion tons and 1.3 trillion cubic meters, respectively, both of which will increase by 8%. The fast growth of carbon emission will be observed

in North and East China, while it would be found in Southwest and East China for WF. The NF and PF will be 21.34 million tons and 2.49 million tons, respectively, both of which will increase by 15%. The rapid growth would be observed in East and Central China for NF and PF, as shown in Figure 3-11.

Figure 3.11 Environmental impacts of food consumption by region in China in 2020 and 2030

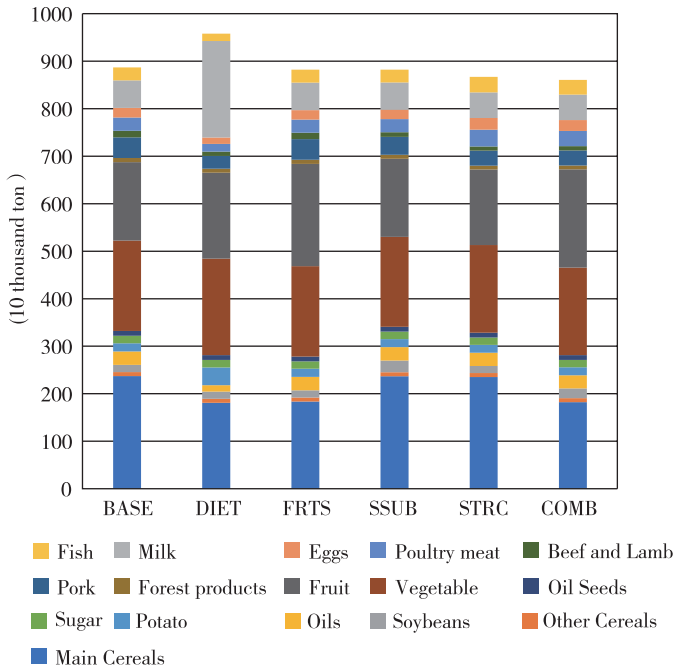


3.3.4 Simulating the Environmental Impacts of Food Consumption under Different Scenarios

Figure 3.12 and Figure 3.13 show the total amount of the supply and demand of food under different scenarios. The CF, WF, NF, and PF related to food consumption are shown in Figure 3.14, Figure 3.15, Figure 3.16, and Figure 3.17, respectively.

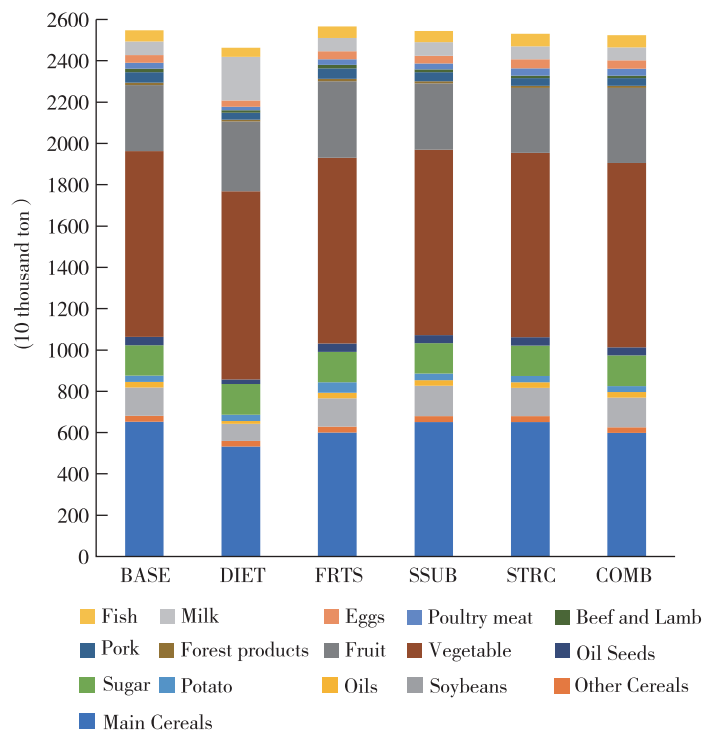
First, the DIET scenario assumes that food consumption patterns in each region follow the dietary guidelines, requiring significant adjustments in the future food consumption structure of residents and significant changes in total food consumption. Nationally, on average, in 2030, the consumption of staple foods, edible oils, and animal foods will decrease, while the consumption of dairy, vegetables, and fruits will increase. Staple food consumption will decrease by 24 percent

Figure 3.12 National food consumption under different scenarios in China in 2030



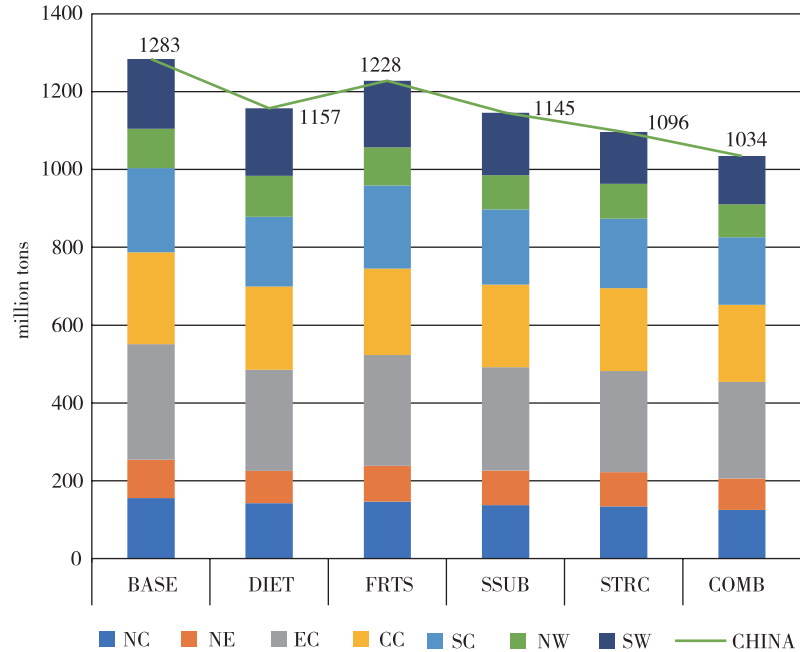
Source: CAU-AFS model results.

Figure 3.13 National food supply under different scenarios in China in 2030



Source: CAU-AFS model results.

Figure 3.14 Total carbon emissions by regions under different scenarios in China in 2030



Source: CAU-AFS model results.

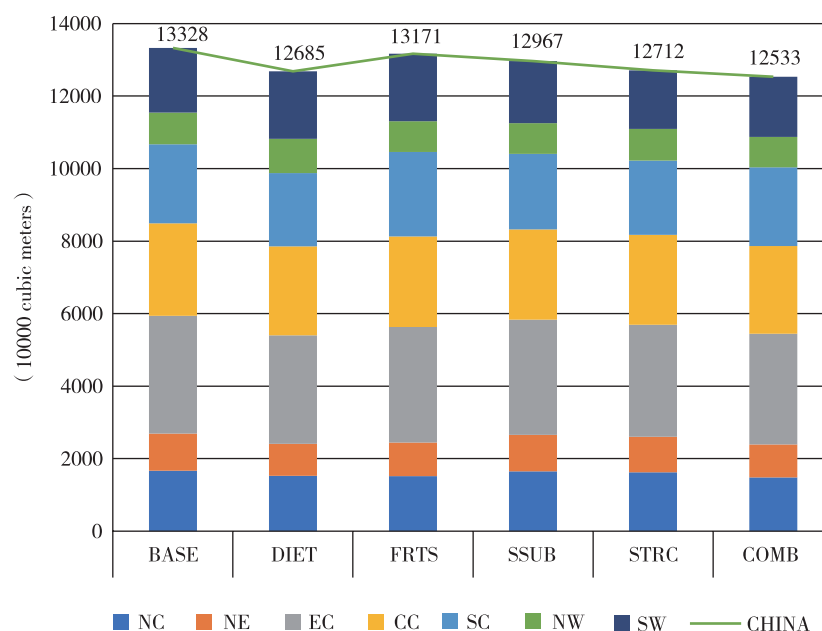
Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest

and only 180 million tons for direct food consumption, and potato consumption will increase by 1.2 times (37.56 million tons), but edible oil will decrease by 53 percent to only 13.38 million tons, and direct consumption of animal

products except milk will decrease by 30 to 40 percent. At the same time, dairy food consumption will increase by 2.5 times, from 58 million tons to 200 million tons.

The restructuring of food consumption has an

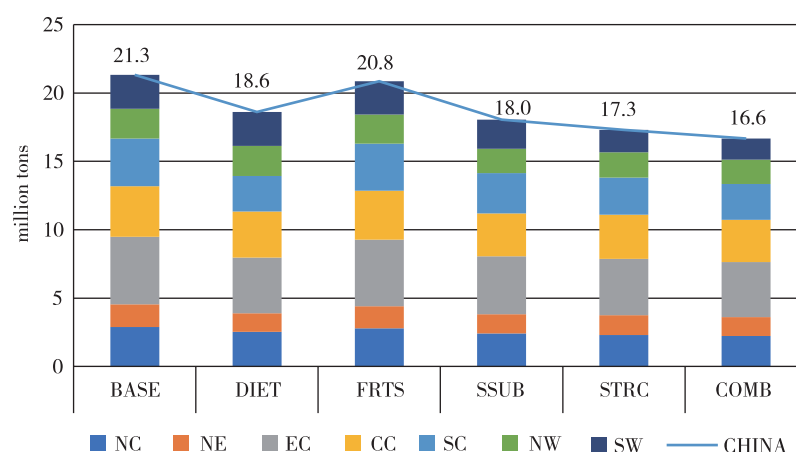
Figure 3.15 Total water footprint by region in China under different scenarios in 2030



Source: CAU-AFS model results.

Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest

Figure 3.16 Nitrogen footprint by region in China under different scenarios in 2030



Source: CAU-AFS model results.

Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest

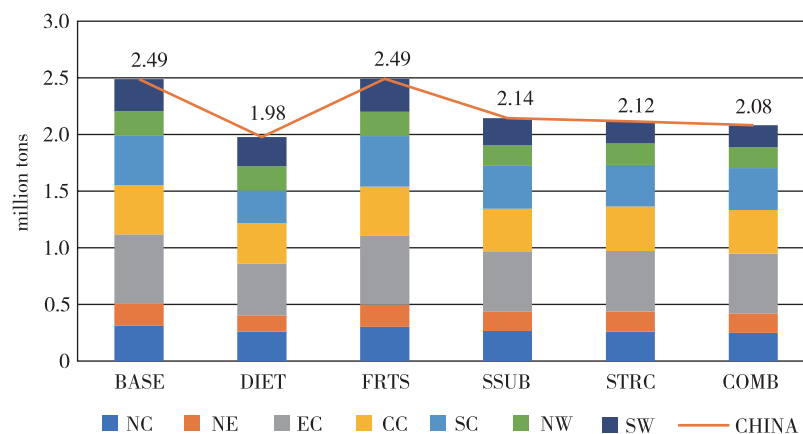
important impact on food supply. To meet changes in food consumption, both staple food and animal food supplies will decline significantly. On the one hand, direct consumption of staple foods will decrease; on the other hand, the demand for feed grains will also decline due to the reduced consumption of animal food. This will result in a significant decline in the supply of staple foods. When following the recommended dietary consumption, the supply of staple food can be reduced by 120 million tons, with a decrease rate of 18 percent, and the supply

of animal products other than milk will be reduced by 51.45 million tons, with a decrease of 37 percent. The supply of fruits and vegetables will increase.

Environmental impacts change significantly along with food consumption. First, under the DIET scenario, carbon emissions will decline wide space. percent from 1.28 billion tons to 1.16 billion tons in 2030 compared to the baseline scenario. The largest decrease (16 percent) is found in Northeast and South China due to the largest



Figure 3.17 Total phosphorus footprint by region in China under different scenarios in 2030



Source: CAU-AFS model results.

Note: NC=North China, NE=Northeast, EC=East China, CC=Central China, SC=South China, NW=Northwest, SW=Southwest

reduction in cereals and meat consumption. A little decrease is shown in the Southwest region, while a slight increase of 3.7 percent is found in the Northwest region. The increase in carbon emissions mainly comes from the significant increase in dairy consumption, which will bring a 2.5-fold increase in carbon emissions from 87.67 million tons to 300 million tons in 2030, with an increase in the share of carbon emissions from 6 percent to 26 percent. The decrease in carbon emissions comes mainly from the decline in staple food and animal products consumption, which decreases by nearly 70 million tons and 260 million tons, respectively, offsetting the increase in carbon emissions from the increased demand for dairy consumption. The results for WF, NF, and PF are similar. WF decreases by 4.8 percent compared to the baseline scenario, with the largest decrease of 13.5 percent in the Northeast, but increases by 8.2 percent and 4.5 percent in the Northwest and Southwest regions, respectively. The national NF and PF decrease by 12.8 percent and 20.5 percent on average, respectively.

Scenario 2, FRTS, assumes an increase in fruit consumption and a reduction in cereal consumption, leaving other products unchanged. It shows that in 2030, carbon emissions will decrease by 4 percent from 1.28 billion tons to 1.23 billion tons compared to the baseline scenario. WF will decrease by 1.2 percent, with a decrease of 9 percent in North and Northeast China and an increase of 7.2 percent in South China. NF will decrease by 2.3 percent, and PF will remain relatively stable.

Scenario 3 is SSUB, which aims to reduce the

pressure on the environment by increasing soybean consumption as a substitute for pork, beef, and lamb consumption. It shows that carbon emissions will decline by 10.8 percent from 1.28 billion tons to 1.15 billion tons in 2030 compared to the baseline scenario, with a larger reduction of 13.8 percent in the Northwest region. WF will decrease by 2.7 percent compared to the baseline scenario, and NF and PF will also decline significantly by 15.4 percent and 13.8 percent on average nationwide, respectively.

Scenario 4, STRC, aims to reduce the consumption of pork, cattle, and sheep by 30 percent (17 million tons) and increase the equivalent amount of poultry meat, eggs, fish, and shrimp by adjusting and optimizing the structure of animal food consumption and choosing a more environmentally friendly animal food intake. It shows that in 2030, carbon emissions will drop by 14.6 percent to 1.09 billion tons compared to the baseline scenario. The largest decrease of 25.3 percent is found in the Southwest region, followed by South China with a decrease of 17.5 percent. WF will decrease by 4.6 percent compared to the baseline scenario, among which the Southwest region has the largest decrease of 9.2 percent. The national NF and PF will decrease by 18.93 percent and 15 percent on average, respectively.

The final scenario is COMB. It combines the scenarios 2, 3, and 4 and aims to promote sustainable and healthy diets by rationally reducing staple food and meat consumption; optimizing the structure of meat consumption; and increasing the consumption of foods such as fruits, soybeans, poultry, eggs, and



aquatic products. Under this scenario, compared with the baseline scenario, the carbon emissions related to food consumption will be reduced by 250 million tons or 19.4 percent in 2030, with the largest reduction of 30.7 percent in the Southwest region. The total national WF will decrease by 6.0 percent, with the largest reductions, by 11 percent, in North and Northeast China; WF will be almost unchanged in Central China. NF and PF from national food consumption will decrease significantly by 21.9 percent and 16.3 percent, respectively, with the largest reductions in Southwest China by 38.3 percent and 30 percent, respectively.

Overall, our simulation results demonstrate that each of the five scenarios for transitioning to a sustainable and healthy diet has its unique advantages. While the DIET scenario can reduce carbon emissions, it still faces environmental pressures, The FRTS scenario provides more micronutrients and is more environmentally friendly. The SSUB scenario significantly reduces the pressure on resources and the environment while promoting human well-being. In comparison, the STRC scenario shows that changing the structure of meat consumption based on food resources also is a good option for transiting to a sustainable diet. It also shows that white meat is better for human nutritional health than red meat and has positive impacts on the environment. Under the COMB increasing the consumption of fruits and soybeans, reasonably reducing cereal and meat consumption, and simultaneously restructuring meat consumption will contribute to transiting to a sustainable and healthy diet.

3.4 Conclusions and Policy Implications

3.4.1 Main Conclusions

This chapter aims to estimate and compare the environmental impacts of food consumption in different regions. It further explores the potential for reducing these impacts while safeguarding nutritional health and promoting the green transformation of the agrifood system through change and optimization based on the China Agricultural University Agrifood System Model. The main findings are highlighted below.

Firstly, or To begin with, as people's living standards continue to rise, dietary imbalance has become more

prominent, leading to serious health risks and increased pressure on resources and the environment. the problem of dietary imbalance has become increasingly prominent, which not only poses serious challenges to human health but also puts more pressure on resources and the environment. The national per capita CF, WF, NF, and PF related to food consumption were 0.83 tons, 878 cubic meters, 13.2 kilograms, and 1.5 kilograms, respectively, in 2020. Total carbon emissions associated with food consumption were 1.18 billion tons, accounting for 9 percent of the total national carbon emissions. Cereal and meat consumption were dominant in environmental impacts, with shares of 27 percent and 48 percent in total carbon emissions, respectively, and 30 percent of total WF. Meat is an important source of NF and PF, accounting for 66 percent and 59 percent, respectively. There are large differences across regions, with the Northeast's having the highest carbon emissions and water consumption per capita, and the Northwest's having the highest NF and PF.

Secondly, food consumption is projected to have a significant impact on the environment as economic development and urbanization continue to increase. Both carbon emissions and WF from food consumption nationwide are expected to increase by 8 percent in 2030. Fast growth of carbon emissions is found in Northern and Eastern China, while fast growth of WF is observed in Southwest and Eastern China. In addition, both NF and PF are projected to increase by 15 percent nationwide.

Thirdly, the dietary pattern recommended by the Dietary Guidelines for Chinese Residents (2022) falls short of being sustainable and healthy. The main reason for this is that milk consumption is very low comparing with the recommended dietary intake, which needs to be increased by more than two times, thereby exacerbating the pressure on resources and the environment. Additionally, it is challenging to difficult to guarantee from the supply side, with domestic milk production of less than 40 million tons in 2021. The increased environmental impact of milk consumption would largely offset the positive environmental effect due to the significant reduction of cereals and animal products consumption.

Finally, there are ample opportunities to optimize for optimizing sustainable and healthy dietary patterns



of Chinese residents. Such optimization could involve considering food resources from different regions, reducing refined cereal consumption, increasing fruit consumption, replacing meat with soybean consumption, or adjusting the meat consumption structure by decreasing pork, beef, and lamb consumption and increasing poultry, eggs, and aquatic products consumption. These changes could lead to a reduction in environmental impacts while ensuring adequate nutrition. Under the scenarios of COMB, carbon emissions from food consumption can be reduced by 19 percent (250 million tons) nationwide compared with the baseline scenario, with a reduction of up to 30 percent in Southwest China. WF can be reduced by 6.0 percent on average, with a reduction of more than 11 percent in North and Northeast China. NF and PF can be reduced by 21.9 percent and 16.3 percent, respectively, with a reduction of up to 38.3 percent and 30.5 percent in Southwest China, respectively. Notably, the reduction of nitrogen and phosphorus footprint in Southwest China was as high as 38.3 percent and 30.5 percent, respectively.

3.4.2 Policy Implications

Four policy implications were proposed based on our main findings:

First, optimizing dietary structure is an important measure to ensure human well-being, protect the environment, and achieve carbon neutrality. However, due to various environmental impacts of food consumption and production, a cross-sectoral coordination mechanism need to be established at the national and regional levels. This will allow for the joint development of "sustainable and healthy diets" guidance, which can actively guide food consumption towards sustainable and healthy practices.

Second, to build sustainable and healthy dietary patterns, the food supply structure should be adjusted. Moreover, support for research and development, as well as production subsidies for foods such as beans, fruits, poultry, and aquatic products, must be increased. This will enhance the diversity of the food supply and promote sustainability and accessibility of food.

Third format measures of optimizing the food consumption structure, accelerating the promotion of the

transition toward green and low carbon food production, distribution, and household consumption, shortening food transportation distances, and reducing food losses and energy use can contribute to reducing CF, WF, NF, and PF and reduce the environmental impact of food consumption.

Finally, there are large disparities in the data on food consumption across different departments, and there is a lack of authoritative and uniform coefficients of the environmental impact factors. Therefore, it is crucial for different departments to work together in building basic data so that it can be more scientific and transparent. From different departments in building basic data to make the data more scientific and transparent. More in-depth studies on sustainable and healthy diets for Chinese residents should be conducted to better inform relevant policy on promoting sustainable diets.

References

- Academy of Global Food Economics and Policy (AGFEP), China Agricultural University, China Academy of Rural Development (CARD), Zhejiang University, Center for International Food and Agricultural Economics (CIFAE), Nanjing Agricultural University, Institute of Agricultural Economics and Development (IAED), Chinese Academy of Agricultural Sciences, and International Food Policy Research Institute (IFPRI). China and Global Food Policy Report [R]. Beijing: Academy of Global Food Economics and Policy Research, 2021.
- Academy of Global Food Economics and Policy (AGFEP), China Agricultural University, China Academy of Rural Development (CARD), Zhejiang University, Center for International Food and Agricultural Economics (CIFAE), Nanjing Agricultural University, Institute of Agricultural Economics and Development (IAED), Chinese Academy of Agricultural Sciences, and International Food Policy Research Institute (IFPRI). China and Global Food Policy Report [R]. Beijing: Institute for Global Food Economics and Policy Research, 2022.
- Cai, H., Biesbroek, S., Wen, X., Fan, S., van 't Veer, P., Talsma, E.F., 2022. Environmental footprints of Chinese foods and beverages: Literature-based construction of a LCA database. *Data Br.* 42, 108244.
- He P, Baiocchi G, Feng K, Hubacek K, Yu Y. Environmental impacts of dietary quality improvement in China. *J Environ Manage.* 2019 Jun 15; 240:518-526. doi: 10.1016/j.jenvman.2019.03.106. Epub 2019 Apr 15. PMID: 30999146.



- Poore, J., Nemecek, T., 2018. Reducing food's environmental impacts through producers and consumers. *Science* (80-.). 360, 987–992.
- Springmann, M., Clark, M., Mason-D'Croz, D. et al. Options for Keeping the Food System within Environmental Limits. *Nature*, 2018, (562): 519-525.
- Sheng F., Wang J., Chen K. Z., Fan. S, Haixiu Gao. Changing Chinese Diets to Achieve a Win-Win Solution for Health and the Environment. *China & World Economy*, 2021. 29(6):34-52.
- Song, G., Li, M., Semakula, H.M., Zhang, S., 2015. Food consumption and waste and the embedded carbon, water and ecological footprints of households in China. *Sci. Total Environ.* 529, 191–197.
- Springmann, M., Clark, M., Mason-D'Croz, D. et al. Options for Keeping the Food System within Environmental Limits. *Nature*, 2018, (562): 519-525.
- Sun, Z., Scherer, L., Zhang, Q. et al. Adoption of plant-based diets across Europe can improve food resilience against the Russia-Ukraine conflict. *Nat Food* 3, 905–910 (2022). <https://doi.org/10.1038/s43016-022-00634-4>
- Wu, H J, et al. 2022. A new dietary guideline balancing sustainability and nutrition for China's rural and urban residents. *iScience*, 25(10), 105048.
- Xue L, Liu X, Lu S, Cheng G, Hu Y, Liu J, Dou Z, Cheng S, Liu G. China's Food Loss and Waste Embodies Increasing Environmental Impacts. *Nature Food*. 2021, 2 (7), 519-528.

Chapter 4

Trade, FDI, and the Transition of Chinese Diets

Xu Tian,^{1,2} Faqin Lin,^{1,2} Xuejun Wang,^{3,4} Wei Si^{1,2}

1. Academy of Global Food Economics and Policy, China Agricultural University

2. College of Economics and Management, China Agricultural University

3. Center for International Food and Agricultural Economics, Nanjing Agricultural University

4. College of Economics and Management, Nanjing Agricultural University



Key Findings

- International trade and foreign direct investment (FDI) reshape the structure of agricultural production, change food prices, influence income levels across various industries, alter dietary preferences, and facilitate growth in the food processing industry, thereby affecting residents' diets.
- International trade and FDI change the dietary structures of different countries, lead to a rise in the consumption of meat and processed food (especially sugary beverages) among residents of developing countries, and consequently reduce undernutrition but elevate the risk of obesity.
- Trade openness has elevated Chinese residents' consumption of vegetables, beans (and nuts), fish, packed and processed foods while reducing their demand for grains and fruits, resulting in an increasing share of calories drawn from protein, fat, and nonstaple foods but also a decrease in dietary diversity and daily calorie intake.
- The inflow of international capital into China's food industry (for example, Western fast-food chains like McDonald's and KFC) has increased the intake of dietary energy and fat by Chinese residents, increased the likelihood of beverage consumption, and significantly amplified the probability of individual becoming overweight.

Policy recommendations

- Trade and FDI may increase the risk of obesity; thus, promoting a healthy diet is very important to mitigate the negative impact of globalization.
- To further liberalize restrictions on FDI in the food industry, it is necessary to reduce limitations on qualification requirements, equity ratio, business scope, and investment methods. Additionally, FDI should be directed toward investing in nutritious and healthy food production, processing, and cold chain logistics as well research and development of nutrition-oriented agricultural science and technology. This will help to improve the nutritional status of the national diet.
- To avoid and mitigate the negative impact of FDI on the nutritional status of Chinese people, it is important to promote the refinement and implementation of China's FDI review and regulatory systems in the food industry by clarifying the direction of FDI, key tasks, and in-process and postsupervision measures.
- It is also essential to include the goal of improving dietary nutrition in future World Trade Organization (WTO) negotiations and to make full use of both domestic and international food markets and resources to safeguard national food security.



4.1 Introduction

Due to differences in food resource endowments, climate and geography, culture, religious beliefs, population density, and other conditions across the world, each region has developed its own distinctive food culture and dietary preferences. However, these dietary patterns are not static. Economic development (such as urbanization, income growth, price fluctuations), social evolution (such as changes in lifestyle, women's empowerment), cultural differences (such as religious beliefs, environmentalism), and technological progress (such as advancements in food production, processing, storage, and cooking) can all affect the dietary structure and preferences of residents (Popkin et al. 2012; Thow 2009; Dithmer and Abdulai 2017; Azzam 2021).

In the past two decades, the effects of trade and FDI on regional dietary patterns have become increasingly prominent, garnering widespread attention from academia. On the one hand, trade and FDI can improve the diversity of food choices in various regions (Krivonos and Kuhn 2019), alleviate malnutrition, improve food security (Dithmer and Abdular 2017), promote competition and specialization in the food industry, and

enhance the resilience of the food system to external shocks (Kummu et al. 2020). On the other hand, many studies have demonstrated that trade openness can accelerate dietary transition in developing countries, leading to increased consumption of unhealthy foods. For instance, after opening up to trade, Western fast food flooded into developing countries, increasing residents' preference for sugary drinks and fried foods in countries such as Vietnam (Schram et al. 2015), Peru (Baker et al. 2016), India (Law 2019), and Mexico (Giuntalla et al. 2020) and elevating the risk of overweight and obesity among residents (Miljkovic et al. 2015). In recent years, China has imported around 100 million tons of soybeans annually from the international market, which has significantly eased China's domestic feed grain shortage; promoted the development of the livestock, poultry, and aquaculture industries; and improved the meat consumption level of Chinese residents. However, it has also reduced the relative price of edible oil, leading to excessive consumption of vegetable oil (Popkin et al. 2012).

China is the world's largest importer of agricultural products, with the value of agricultural product imports reaching \$272.80 billion in 2021. Due to pressures arising from resource scarcity, increased environmental



constraints, and upgraded food demand in agriculture, it is essential to thoroughly analyze how trade and FDI affect diets and consider how to leverage the international market to facilitate China's transition to a sustainable and healthy dietary model.

This chapter examines the current state of global

agricultural trade and FDI, analyzes their impacts on dietary structure and nutrition transitions, summarizes the main empirical evidence and findings from current literature, and considers how trade rules and FDI policies can be used to promote sustainable and healthy diets in developing countries such as China.

Box 4.1 China's Dietary Transition and Soybean Import

Soybeans play an essential role in the diet of Chinese residents and in livestock breeding as they are a critical source of plant protein, edible oil, and protein feed. With the dietary structure of urban and rural residents shifting toward animal foods such as meat, milk, aquatic products, and eggs (Zhao and Zheng 2015), the demand for soybean feed and soybean oil continues to grow. In 2022, China consumed 116 million tons of soybeans, with soybeans' ranking fourth in agricultural product consumption (Tang and Li 2022). Due to its limited arable land resources, China prioritizes grain production, particularly rice and wheat, to ensure the "absolute safety of rice and wheat." Consequently, the arable land resources available for soybean cultivation are limited. To meet the growing demand for soybeans in the aquaculture industry and among residents, China has imported a large quantity of soybeans from the international market in recent years. In 2022 alone, China imported 91.08 million tons of soybeans, accounting for 79 percent of total domestic consumption.

Soybean imports have further promoted the dietary transition of Chinese residents. On the one hand, when pressed, cheap imported soybeans become the primary source of protein feed for livestock production and edible vegetable oil for residents. This promotes the development of the livestock and poultry breeding industries, meets residents' needs for vegetable oil, and makes imported soybeans an essential part of the diversified food supply channels under the "greater food concept." On the other hand, imported soybeans have had negative impacts on China's agricultural food system, primarily in two respects. First, it affects the sustainability of agricultural production. The cheap import of soybeans has reduced the market price of domestic soybeans and affected the comparative income of soybean growers. To maximize benefits, the traditional grain-bean rotation system in Northeast China has been gradually replaced by corn monoculture, which has broken the original farming system that combined land use and cultivation. This has created problems such as decreased soil enzyme activity, imbalance of the soil microbial community, and decreased soil fertility (Bennett et al. 2012; Chavarria et al. 2016). Second, it increases the health risks caused by excessive fat intake. The oil yield of imported soybeans is relatively high, generally between 19 and 20 percent (Zhai Tao and Wu Ling 2020). Taking into account the 91.08 million tons of soybeans imported by China in 2022, around 72.86 million tons of soybean meal and 18.21 million tons of soybean oil can be produced after pressing. The sharp increase in soybean oil production has reduced the price of soybean oil, leading to increased consumption by residents. According to data from the US Department of Agriculture, soybean oil consumption in China has risen from 11.40 million tons in 2010 to 17.60 million tons in 2020, even exceeding the total consumption of edible oil (about 15.46 million tons) which is estimated according to the recommended amount of cooking oil in the Dietary Guidelines for Chinese Residents (2022). Excessive edible oil consumption can lead to conditions including hypertension, hyperlipidemia, and other notable diseases. Imported soybeans also squeeze the proportion of nonsoybean vegetable oil in residents' vegetable oil consumption, which is not conducive to promoting diversified dietary choices. According to data from the US Department of Agriculture, the proportion of total vegetable oil consumption in China accounted for by soybean oil has increased from 25.10 percent in 2000 to 45.60 percent in 2022. Therefore, it is necessary to be vigilant about the resource environment and nutritional health problems created by the increase in soybean imports.

4.2 Global Agricultural Trade and FDI

4.2.1 Current Situation of Global Agricultural Trade

Trade has made world agriculture increasingly closely linked, with the trade of agricultural products in

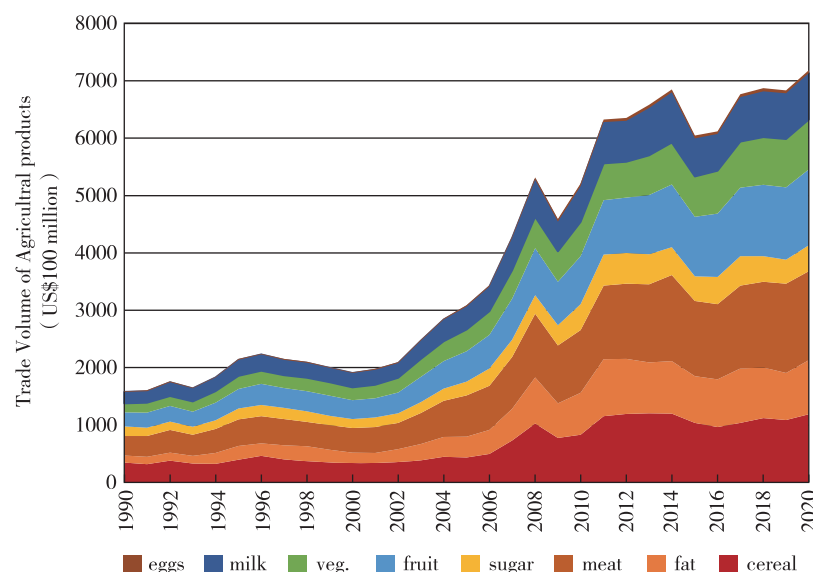
particular developing rapidly while exhibiting a steady growth trend (Figure 4.1). From 1990 to 2020, the total trade of agricultural products globally increased from US\$319.44 billion to US\$1492.21 billion, an increase of 3.67 times. While the scale of agricultural trade has grown rapidly, the trade structure of agricultural products has also tended to be diversified and balanced. In 2020,



the meat and fruit trades accounted for the largest proportion of the eight major agricultural products, at \$155.21 billion and \$131.92 billion, respectively. The trade volume of grain, the main food source in the world, was \$118.94 billion. However, the growth rate of grain was lower than that of other agricultural products. By comparison, the growth rate of oil and vegetable trade was the largest, increasing by 6.68 and 4.50 times,

respectively, followed by fruit, meat, milk, eggs, and sugar, which increased by 4.42, 3.56, 3.09, 2.88, and 1.70 times. The global demand for agricultural products has gradually shifted from satisfying food and clothing needs to pursuing dietary balance. The global trade structure of agricultural products led by demand has shown the characteristics of the grain-based trade structure.

Figure 4.1 Trends of the global agricultural trade from 1990 to 2020



Source: Data are from the FAOSTAT database.

Note: veg. = vegetables.

4.2.2 Trends in Global Agricultural Trade Tariffs

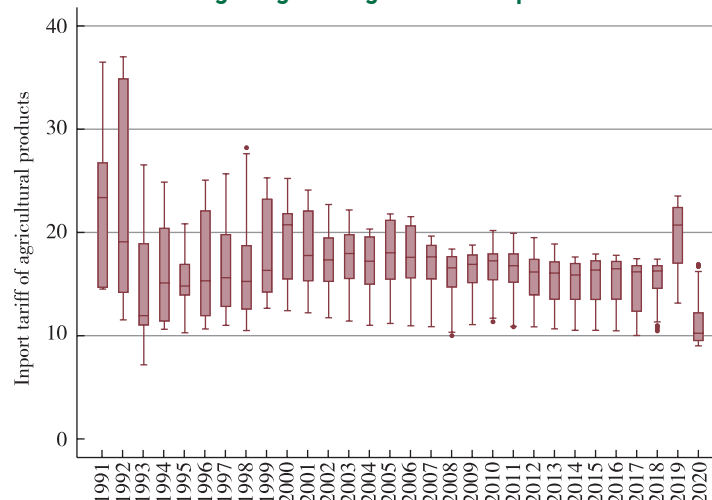
The rapid development of agricultural trade is inseparable from the reduction of agricultural import tariffs. Since 1991, import tariffs for agricultural products have generally shown a downward trend, but after the 10-year implementation period of the WTO (i.e., after 2004), this downward trend has gradually slowed (Figure 4.2). Before the establishment of the WTO, there were large differences in agricultural tariffs. Over time, these differences gradually narrowed. This is specifically reflected in the decline of the maximum tax rate year by year and the small fall in the minimum tax rate, which shows that there have been structural changes in global agricultural import tariffs, with most countries (or regions) having adjusted to lower tariffs.

4.2.3 Current Situation of Global Agriculture-related FDI

After the world food crisis in 2007–2008, many countries began searching for overseas resources as their reserve resources, with agriculture-related FDI continuing to rise. The inflow of agriculture-related FDI often brings more abundant capital to the local area, enabling the expansion of production and sales. It also positively affects the agriculture-related industries of the host country, promotes the intensification of market competition, increases the variety and output of products, reduces the price of agricultural products, and promotes industrial growth and efficiency, thus bringing further significant economic benefits. From 1991 to 2019, the total inflow of agriculture-related FDI globally increased from \$0.16 billion to \$4.85 billion, while the total outflow



Figure 4.2 Time series change of global agricultural import tariffs from 1991 to 2020



Source: Data are derived from the World Integrated Trade Solution (WITS).

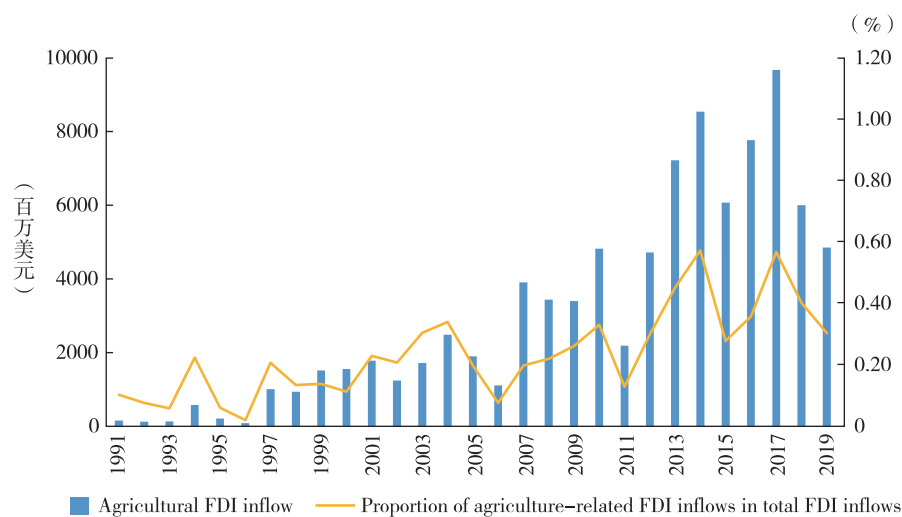
Note: The import tariff of agricultural products is calculated by summing up the most-favored nation simple average tariff of animals, vegetables, and food in the WITS product classification with the trade volume as the weight. The line in the box is the median value of the annual global agricultural import tariff, and the upper and lower boundaries of the box are the 75th and 25th percentiles of the annual global agricultural import tariff.

of agriculture-related FDI increased from \$0.14 billion to \$0.23 billion. Agriculture accounts for a small proportion of the total global FDI inflows and outflows compared to other economic sectors. From 1991 to 2019, agriculture accounted for less than 1 percent of total FDI inflows and outflows. In addition, having been affected by the global food crisis, both the inflow and the outflow of agriculture-related FDI fluctuated rapidly after 2007, peaking in 2014, and exhibited a downward trend thereafter (Figures 4.3 and 4.4).

In the agriculture sector, FDI inflows are relatively

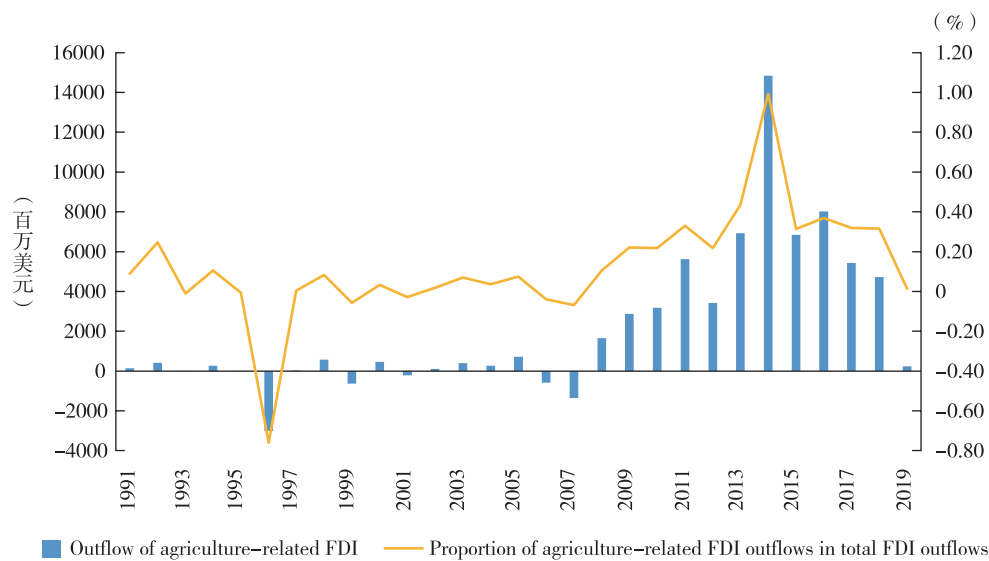
more likely to target resource control, focusing primarily on land (Hallam 2009). In Africa, FDI is mainly concentrated on the production of rice, wheat, oil crops, and flowers; in Asia, the focus is on rice, wheat, meat, and poultry production; in South America, the focus is on fruit, sugarcane, flowers, and soybean production (UNCTAD). In 2019, Indonesia was the largest recipient of agricultural FDI inflows, with an inflow of \$1.84 billion. Norway ranked second with an inflow of \$0.93 billion, followed by the United States with an inflow of \$0.45 billion (Figure 4.5). The significant inflow of FDI in

Figure 4.3 Total agriculture-related foreign direct investment (FDI) inflows and the proportion of agriculture-related FDI inflows to total FDI inflows



Source: Data are from the FAOSTAT database.

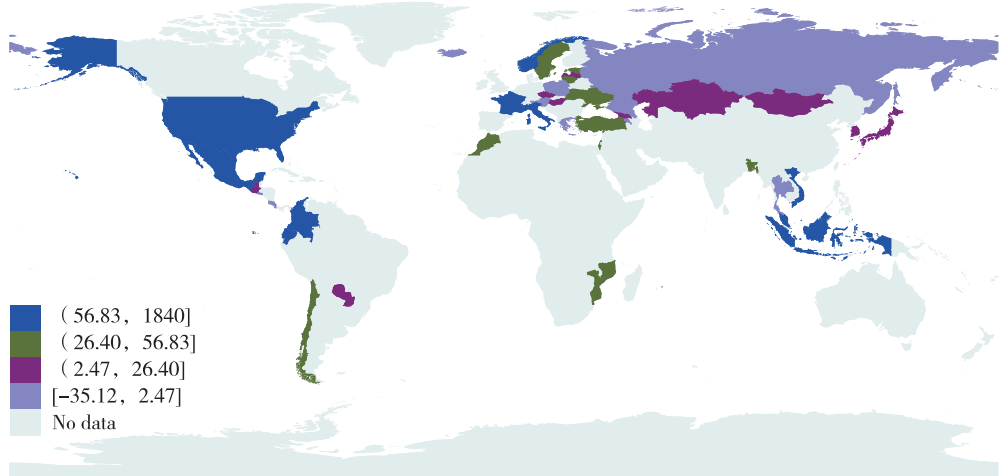
Figure 4.4 Total agriculture-related foreign direct investment (FDI) outflows and the proportion of agriculture-related FDI outflows to total FDI outflows



Source: Data are from the FAOSTAT database.

Note: A negative value indicates that at least one component of FDI is negative and has not been offset by the positive number of other components, which may be due to reverse investment or withdrawal.

Figure 4.5 Agricultural foreign direct investment inflows from countries in 2019



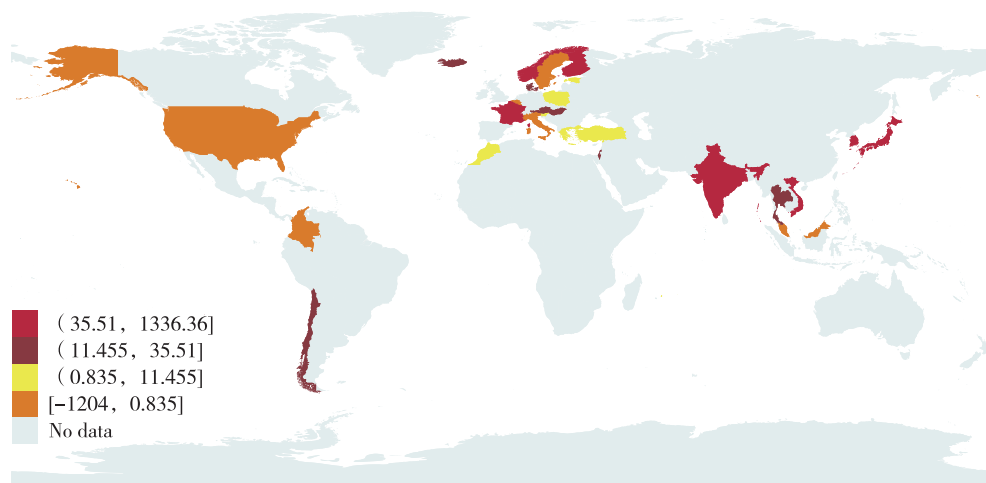
Source: Data are from the FAOSTAT database.

Indonesia's agriculture sector may be attributed to the recent relaxation of FDI regulations, which now allow foreign entities to hold a higher percentage of shares in domestic enterprises. For instance, foreign entities can now own up to 95 percent of local companies in the palm oil production industry (Oxford Business Group 2019). In 2019, India provided the highest amount of FDI in the global agriculture sector, with an outflow of US\$1.34 billion, followed by Norway with an outflow of US\$0.30 billion and Japan with an outflow of US\$0.11 billion (Figure 4.6).

4.2.4 Current Situation of China's Agricultural Trade and Agriculture-related FDI

Because China is a major agricultural country, agricultural trade holds significant importance in its economic development. Prior to China's accession to the WTO, the country's agricultural trade had remained at a low level, with fluctuations. Although there had been an increase in the volume of import and export of agricultural products, the pace had been relatively slow. However, China's integration into the global economy

Figure 4.6 Agricultural foreign direct investment outflows from countries in 2019



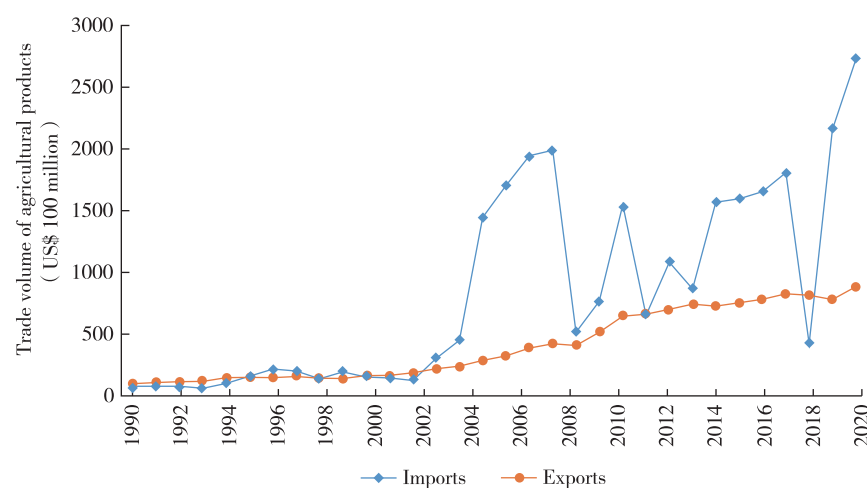
Source: Data are from the FAOSTAT database.

starting in 2001, coupled with the enhancement of the international environment and China's marketization level, allowed China's agricultural trade to enter a new phase of development, characterized by the rapid expansion of the scale of trade and a progressively apparent pattern of trade deficit (Figure 4.7). In 2021, China's agricultural exports reached a total of US\$88.53 billion, while imports amounted to US\$272.80 billion, representing an increase of 4 times and 17 times, respectively, compared with 1990.

Meat, fruit, grain, and aquatic products are the primary agricultural products imported by China. By 2021, China's meat product imports were approximately US\$31.59 billion, grain imports were around US\$19.96 billion, and fruit imports were about US\$15.97 billion, while aquatic product imports were valued at

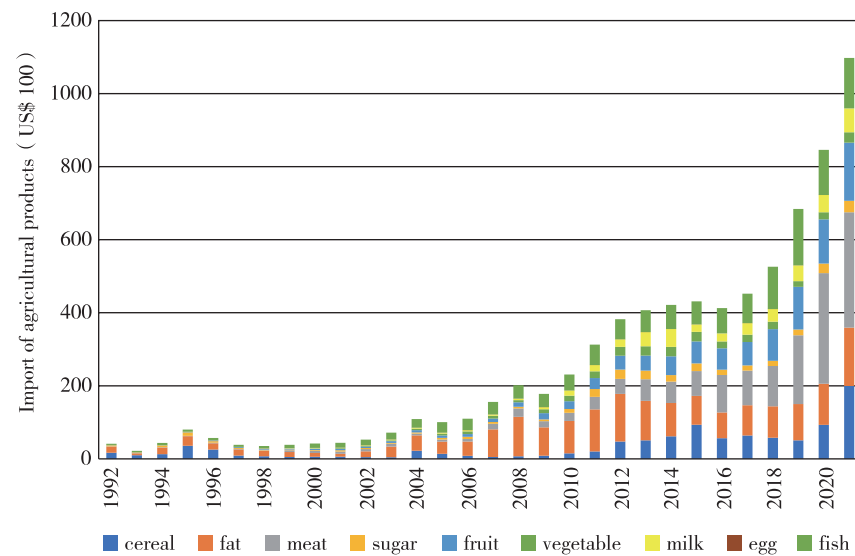
approximately US\$13.81 billion (Figure 4.8). Since 1992, import demands for China's agricultural products have undergone significant changes, with the primary import position of grain gradually being replaced by demand for meat and other products. This change indicates that Chinese residents are increasingly pursuing a nutritious and balanced dietary model. Simultaneously, China's agricultural exports show obvious product heterogeneity, with exports of aquatic products, vegetables, and fruits occupying leading positions. In 2021, China exported approximately US\$11.04 billion worth of aquatic products, US\$10.08 billion of vegetables, and US\$6.33 billion of fruits (Figure 4.9). Other agricultural exports such as milk and eggs account for a small proportion, with limited growth rates. A possible reason for this is that China has a large population and limited per capita land

Figure 4.7 Trends in China's agricultural trade from 1990 to 2021



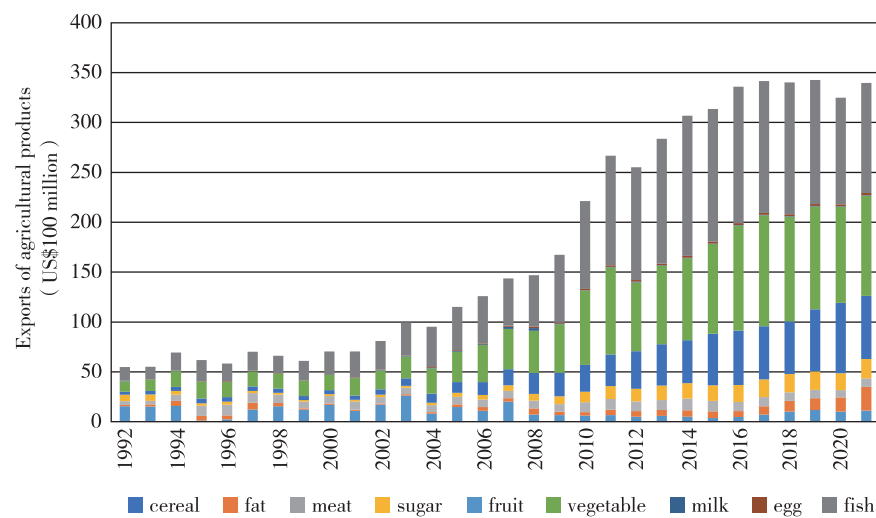
Source: Data are from the World Trade Organization.

Figure 4.8 China's agricultural product imports and its structural changes from 1992 to 2021



Source: Data are from UN Comtrade.

Figure 4.9 China's agricultural product imports and its structural changes from 1992 to 2021



Source: Data are from UN Comtrade.

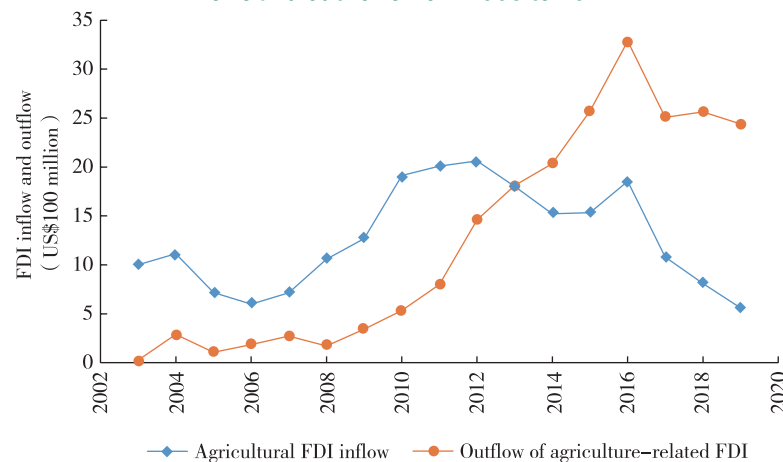
resources, with comparative advantages in the export of labor-intensive products such as aquatic products, vegetables, and fruits.

Due to the loss of land, labor, and other resource endowment advantages, in addition to the worldwide food crisis, China began to shift its focus to overseas markets starting in the early 2000s. Since 2007, China's agriculture-related FDI outflows have grown rapidly, reaching a peak of US\$3.29 billion in 2016 before declining in the time since (Figure 4.10). In 2019, China's foreign agriculture-related FDI reached US\$2.44 billion. At the same time, China's agriculture-related FDI inflows

also exhibited an upward trend, peaking at US\$2.06 billion in 2012 before experiencing a downward trend thereafter. In 2019, China's agriculture-related FDI inflows amounted to only US\$0.56 Billion. Compared to other economic sectors, agriculture accounts for a very small proportion of China's total FDI inflows and outflows. In 2019, China's total FDI inflows and outflows were US\$141.23 billion and US\$136.91 billion, respectively, with agriculture-related FDI inflows and outflows accounting for only 0.40 percent and 1.78 percent, respectively.



Figure 4.10 Trends in China's agriculture-related foreign direct investment (FDI) inflows and outflows from 2003 to 2019



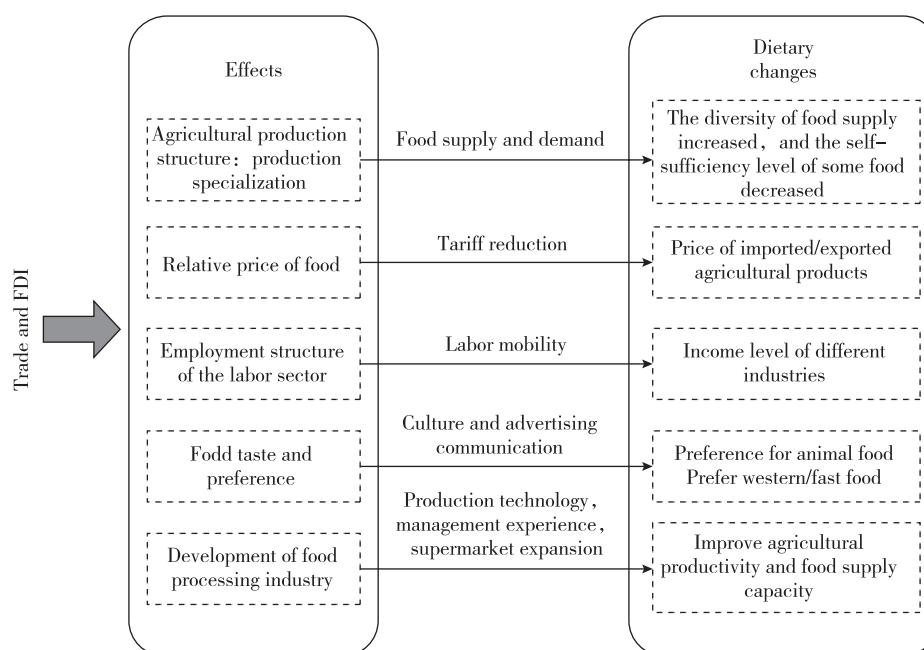
Source: Data are from the FAOSTAT database.

4.3 The Pathways of International Trade and FDI Affecting Dietary Patterns

The substantial growth of global agricultural trade and agriculture-related FDI has become a significant factor in driving the dietary transition of countries, particularly developing nations. Through reviewing existing literature, we have identified five ways in which international trade and FDI affect residents' diets: altering the structure of agricultural production, affecting the relative prices of food, changing the income levels of various industries, influencing dietary preferences, and promoting the development of the food processing

industry. Figure 4.11 shows the specific impact pathways. First, international trade and FDI alter the structure of agricultural production, leading to changes in regional food supply and demand relationships and availability. With the opening of trade, not only do farmers and other food producers face competition from domestic producers, but they must contend with food importers. To improve their international competitiveness, domestic producers gradually specialize and concentrate on producing a few competitive agricultural products. Conversely, some food suppliers that lack comparative advantages rely heavily on the global market. The stronger connections between domestic and foreign food supply systems can have two possible effects on

Figure 4.11 Impact path of trade and foreign direct investment (FDI) on diet





local residents: (1) imported food and FDI can enhance domestic food supply channels and capabilities, helping to smooth fluctuations and increasing the stability of the domestic food supply level while also diversifying the country's overall food supply, and (2) self-sufficiency in some foods may decline, with dependence on imports potentially leading to price fluctuations in the international food market that are then transmitted to the domestic market. In addition, in some remote areas with poor market accessibility, specialization of agricultural production may reduce regional food supply capacity, negatively affecting the quality of residents' meals.

Second, opening up trade reduces import tariffs on agricultural products and increases export demand for some agricultural products. Trade openness is usually accompanied by a sharp reduction in import tariffs on agricultural products, thereby lowering the price of imported agricultural products. Simultaneously, due to the rise in international demand, the price of exported agricultural products may increase, leading to changes in the relative price of food and thus dietary consumption behavior among residents. For instance, cheap soybean imports from China have maintained feed supply for domestic livestock and poultry breeding while reducing feed and vegetable oil production costs.

Third, trade and FDI affect the income of employees in various industries, thereby influencing the affordability of sustainable, healthy, nutritious meals. Trade alters the employment structure of the labor force by promoting the flow of production factors from sectors that no longer have comparative advantages to export sectors that do have them, resulting in heterogeneous impacts on the income of employees in different industries. The change in income levels will affect the ability of residents to afford sustainable, healthy, and nutritious meals.

Fourth, trade and FDI affect residents' dietary tastes and preferences. Globalization leads to the collision and exchange of different cultures. Consumers in underdeveloped regions often imitate the consumption habits of consumers in developed countries, as food consumption is a means of conveying cultural identity and social status. Studies have found that foreign cultures exert a long-term influence on individuals engaged in trade work, leading to changes in their eating patterns. For instance, Law (2019) discovered that Indian residents in more open areas such as coastal regions are more

likely to switch from traditional vegetarian food to animal food than those in other areas. Additionally, the rapid development of information technology permits the food culture in developed countries to easily influence consumers in developing countries through film and television programs and advertisements, luring them into trying new foods—especially sugary drinks such as cola and fried foods such as potato chips. Moreover, the food processing industry in developed countries enters developing countries' markets through the opening of fast-food restaurant chains (such as KFC and McDonald's). These Western fast-food products are popular with urban wage earners and children due to their unique taste, consistent production standards, fast delivery, and convenient availability; however, their high oil and fat content increases the risk of overweight and obesity in developing countries.

Fifth, trade and FDI promote the development of domestic food processing, logistics, and retail industries, thus enhancing the supply capacity of processed food. During the past two decades, agriculture-related FDI has increased thirtyfold, primarily in the grain and oil crop production and livestock breeding and processing sectors (UNCTAD). FDI brings advanced production technologies, crop and livestock varieties, and management experience, improving agricultural productivity and food supply capacity in developing countries. For example, China's cold-chain food logistics significantly developed through the introduction of FDI and increased government investment. From 2011 to 2021, China's total demand for cold-chain food logistics grew by more than 300 percent.¹ At the same time, the construction of cold-chain facilities and equipment significantly improved. By the end of 2020, China's cold-chain logistics market had exceeded CNY 380 billion in value, with a cold storage capacity of nearly 180 million cubic meters and approximately 287,000 refrigerated vehicles—2.40 times, 2.00 times, and 2.6 times that of the capacities recorded at the end of the "12th Five-Year Plan," respectively.² Furthermore, the new round

¹In the past decade, China's total demand for cold-chain food logistics increased by more than 300%. <https://m.gmw.cn/baijia/2022-08/26/1303110103.html>.

²The 14th Five-Year Plan for cold-chain logistics development has been issued, and the modern cold-chain logistics system will be fully built by 2035. <https://baijiahao.baidu.com/s?id=1719001046895881105&wfr=spide&for=pc>.



of scientific and technological revolution and industrial transition, in combination with the rapid promotion of new technologies like big data, the Internet of Things, 5G mobile communications, and cloud computing has effectively empowered all fields and links of cold-chain logistics. This in turn has accelerated the digital transition and intelligent upgrading of cold-chain logistics facilities and equipment, achieving temperature control, process visibility, and source traceability throughout the entire cold-chain logistics system. These advancements can further improve the quality and safety system for fresh agricultural products “from farmland to table, from branches to the tip of the tongue,” meeting the personalized, high-quality, and differentiated food consumption needs of urban and rural residents alike. Additionally, FDI has promoted the development of the food processing industry in developing countries, stimulated the expansion of large supermarkets worldwide, and increased packaged food sales (Hawkes 2006; Popkin 2012). According to Food and Agriculture Organization of the United Nations data, processed food is more likely to occupy the market due to its long-term storage conditions and the growth of infrastructure such as warehousing, logistics, and retail, which affect consumers’ food consumption behavior (Vogli et al. 2014; Reardon 2021).

It is worth noting that trade and FDI strengthen the link between domestic and international markets, implying that the risks of the international market may also affect the dietary consumption of domestic residents through trade and FDI. Thus, extreme weather, outbreaks of animal and plant diseases, public health emergencies, and regional military conflicts all affect global food production, international logistics and transportation, and agricultural supplies. These factors can go on to affect the food trade and meal transition of countries. For example, the Russia-Ukraine conflict resulted in a decrease of at least 35 million tons in Ukraine’s grain output and exports in 2022 in comparison to 2021, which had a serious impact on the food supply and demand of countries involved in food trade with Ukraine. The COVID-19 pandemic also seriously affected the food system supply chain and the agricultural labor supply of many countries and regions, also affecting food consumption. Outbreaks of animal diseases usually lead to bans on meat imports. After the outbreak of mad cow disease in the United

States in 2003, China directly imposed a 13-year beef import ban, altering the source of Chinese beef imports. Thus, it is necessary to fully understand the impact of global emergencies on developing countries’ agricultural trade, study the impact mechanisms and response strategies, and improve overall resilience.

4.4 Empirical Evidence of the Impact of International Trade and FDI on Dietary Patterns

4.4.1 Impact of International Trade on Dietary Patterns

The literature linking trade and dietary structure change focuses on public health and nutritional health. These studies usually take a single country as a case study and use descriptive analysis to explore the relationship between trade-related and diet-related variables. For example, Cassels (2006) found that the increase in global food trade has changed the dietary pattern of Micronesians, making people more dependent on imported food and increasing the consumption of animal food and processed food, which has also led to an increase in the obesity rate. Thow (2009) found that the change in trade policy in Central America promoted an increase in the supply and consumption of meat, dairy products, processed foods, and temperate fruits that affected the health of the region.

Recent empirical studies have assessed the impact of trade on dietary structure and quality, mostly using transnational data or aggregated data from individual countries. Lopez and colleagues (2017) studied 44 low- and middle-income countries and found that the reduction of tariff barriers on the import of sugary beverages led to a significant increase in imports, which increased the sales of sugary beverages and had adverse consequences for obesity and its resulting diseases. Oberlander and colleagues (2017) found that social globalization has increased the supply of animal protein and sugar, which has a negative impact on health, while trade openness by comparison has no direct impact on diet and health. Dithmer and Abdulai (2017) found that trade openness and economic growth positively affect dietary energy consumption, improving dietary diversity and quality related to food safety. Krivonos and Kuhn (2019) found that changes in dietary patterns, reflected in



higher average calorie intake and a more diversified diet, were due to income growth and the shift from a planned and relatively closed country to a more open market economy.

Some studies use household survey data to study the impact of trade on dietary structure and nutrition. Law (2019) found that trade openness has promoted the transition of the diet of residents in rural India from a traditional staple food model to a diet model rich in animal products. Montolalu and colleagues (2022) found that trade liberalization represented by tariff reductions can improve nutrition intake and promote greater food security.

4.4.2 Impact of FDI on Dietary Patterns

FDI is also considered to play an important role in changing the dietary structure. It allows multinational companies to more effectively publicize and market their products while creating demand and adapting to consumer characteristics. FDI has increased competition among local companies, not only increasing the demand for marketing brands but also increasing the demand for the entire food category.

Early research in this area analyzed the relationship between FDI and diet and nutrition as part of the wider debate on the influence of “dependence and modernization” of foreign investment and transnational corporations in developing countries. Recent research has found that the impact of FDI on dietary and nutritional indicators seems to vary from industry to industry. Mihalache and Li (2011) concluded that FDI in the primary sector often damages the food security of low-income countries through resource development, labor market effects, and negative environmental and demographic externalities. However, FDI in manufacturing has also led to modernization, technology and human capital spillovers, and wage increases, thus improving overall nutritional status.

Researchers have found that the impact of FDI on the dietary structure is more reflected in the increase in consumption of sugary and highly processed foods. These findings confirm those of previous studies showing that the level of FDI reduces the impact of gross domestic product on the consumption of unhealthy foods such as soft drinks, ice cream, candy, overprocessed foods, and

packaged foods.

In summary, trade and FDI do affect the national dietary structure, leading to an increase in residents’ consumption of meat and processed food. However, due to the presence of different research objectives and perspectives, there are significant differences in the impact of trade and FDI on the dietary structure of different countries, which cannot be generalized.

4.5 The Impact of Trade and FDI on the Dietary Transition of Chinese Residents

4.5.1 Impact of Trade Liberalization on the Dietary Structure and Nutritional Status of Residents

In the past decade, numerous studies have suggested that trade liberalization plays a crucial role in promoting dietary structure and nutrition transition. Trade affects people’s dietary structure through various channels such as income, price, reconstruction of the food supply chain, availability of imported food, and cultural interaction. In China, we investigated the impact of tariff reductions after China’s accession to the WTO on the dietary structure and nutrition transition of the Chinese people. By using China Health and Nutrition Survey (CHNS) data and constructing the degree of trade openness at the regional level, we found that trade liberalization has had a significant impact on China’s nutrition transition, which we examined from two perspectives: dietary structure and dietary quality.

From a dietary structure perspective, trade openness has increased residents’ consumption of vegetables, beans (and nuts), fish, and packaged and processed foods while reducing consumption of grains and fruits. We divided all food consumption into 10 categories, including 8 categories recommended by the Chinese Diet Pagoda in 2022—grains, vegetables, fruits, beans (and nuts), meat (including poultry), milk (including dairy products), eggs, and fish (including all aquatic products)—as well as two other categories of food—(1) packaged and processed food and (2) beverages. Our research revealed that tariff reductions promoted the consumption of vegetables, beans (and nuts), fish, and packaged and processed food but negatively affected



grain and fruit consumption.³ By comparing estimated consumption coefficients and average values of various foods, we found that vegetable, bean (and nut), fish, and packaged and processed food consumption increased by 5.68 percent, 13.16 percent, 36.70 percent, and 67.00 percent, respectively. By comparison, grain and fruit consumption decreased by 8.60 percent and 21.80 percent, respectively (Table 4.1). We further analyzed the impact of trade liberalization on the heterogeneity of dietary structure from the perspective of urban and rural areas. For rural residents, trade liberalization promoted the consumption of vegetables, beans (and nuts), most animal products (meat, eggs, and fish), and packaged and processed foods while decreasing grain and fruit consumption significantly. In contrast, for urban residents, trade liberalization reduced the consumption of vegetables, fruits, and beans (and nuts) while increasing fish and processed food consumption significantly.

Furthermore, in addition to studying the impact of the overall trade tariff reduction that resulted from China's WTO accession on dietary structure and nutrition transition, we analyzed the effect of import trade liberalization on the largest agricultural product imported by China—soybeans—on residents' dietary consumption. We found that soybean import liberalization significantly promoted Chinese residents' edible oil consumption. From a dietary quality perspective, trade opening has resulted in a decline in food expenditure and a reduction in residents' dietary diversity and daily calorie intake (Table 4.2). However, the share of calories obtained from protein, fat, and nonstaple foods has increased. Improving dietary quality is a key aspect of nutrition transition (Tian and Yu 2015). In this study, we selected three indicators to measure dietary quality: dietary cost, dietary diversity, and caloric source. We used CHNS data to measure each indicator according to specific

criteria. We multiplied the average price of each food category by the daily consumption of corresponding food to measure individual meal cost. The total number of food types consumed during the survey was used as a measure of dietary diversity. Daily intake of dietary calories and the share of calories obtained from protein, fat, and nonstaple foods were used as indicators of the source of calories. Daily caloric intake per capita is the most widely used indicator to measure malnutrition in developing countries because it is consumers' primary need (Subramanian and Deaton 1996; Meng et al. 2009; Ogundari and Abdulai 2013). Once individuals or families consume enough calories to avoid hunger, their demand for non-calorie-specific attributes such as taste, smell, and appearance will increase (Behrman and Doelaliker 1987; Jensen and Miller 2010; Baylis et al. 2019), marking the beginning of the nutrition transition. Previous studies have found that people's share of calories from fat, protein, and nonstaple foods increases during the nutrition transition (e.g., Tian and Yu 2015; Baylis et al. 2019). Next, we will show the results of the impact of trade liberalization on aforementioned dietary quality indicators.⁴

From the results of dietary costs, our research found that trade liberalization led to a decline in food expenditure. Specifically, a 10.00 percent decline in the tariff rate will lead to a 0.22 yuan decrease in daily food expenditure and a 0.41 yuan decrease in the cost of healthy food, accounting for about 1.89 percent and 2.45 percent of their respective average values.⁵ The impact of tariff reduction on food expenditure in urban areas

³The benchmark model is $y_{ijt} = \beta_0 + \beta_1 \text{tariff}_{jt} + \delta Z + v_i + \mu_t + \varepsilon_{it}$, where y_{ijt} measures the daily consumption of 10 food categories (i.e., cereals, vegetables, fruits, beans, meat, milk, eggs, fish, packaged and processed food, and beverages), i is an index for the individual, j is for the prefecture, and t is for the year. Moreover, tariff_{jt} represents the prefecture-level tariff reductions by taking a weighted average of the four-digit code based on the employment structure of each prefecture, while Z refers to other variables that have been noted to affect individual food consumption, including individual characteristics (i.e., age, gender, educational attainment, physical activity level) and family demographic structure (i.e., household size, share of older individuals, share of children). We also control for per capita household income and food prices based on demand theory.

⁴Based on the previous benchmark regression model, the explained variables are changed into dietary diversity, calorie intake, protein share, fat share, and nonstaple food calorie share. Among them, dietary diversity is measured by the types of food consumed during the survey period in CHNS data; calorie intake is measured by daily average calorie intake; and protein share, fat share, and nonstaple food calorie share are measured by the proportion of protein, fat, and nonstaple food in all calorie intake, respectively.

⁵The regression model is $e_{ijt} = \beta_0 + \beta_1 \text{tariff}_{jt} + \eta M + v_i + \mu_t + \varepsilon_{it}$, $he_{ijt} = \beta_0 + \beta_1 \text{tariff}_{jt} + \theta C + v_j + \mu_t + \varepsilon_{it}$, where, e_{ijt} and he_{ijt} respectively, represent the individual food expenditure (i.e., the sum of expenditure spent on each food category) and the cost of a healthy diet in each community. The cost of a healthy diet in each community is obtained by multiplying the median of the recommended consumption of each type of food by the price of each type of food in each community and adding up all the kinds of food required. M and C refer to other factors that may affect the dietary costs at the individual and community levels, including food prices, household and personal characteristics, and regional heterogeneity.



Table 4.1 Impact of trade liberalization on food consumption structure

	Variable	Cereal	Vegetable	Fruit	Beans	Meat
Total sample	log(tariff)	422.22***	-165.78**	100.45***	-60.25**	-10.44
Rural sample	log(tariff)	462.78***	-492.85***	139.03***	-184.55***	-131.39***
Urban sample	log(tariff)	-7.94	580.18***	196.49**	174.65***	74.33
	Variable	Milk	Egg	Fish	Packaged and processed food	Beverage
Total sample	log(tariff)	5.60	-10.03	-107.69***	-62.77***	-12.97
Rural sample	log(tariff)	14.65	-40.70***	-150.66***	-59.05***	-5.14
Urban sample	log(tariff)	-36.21	-16.91	-99.56**	-41.08*	-6.62

Source: Data are drawn from China Health and Nutrition Survey (CHNS) 1997-2011.

Note: Tariff = weighted tariff level at the regional level. The control variables include household per capita income, food price, personal characteristics (e.g., age, gender, education level, physical activity level), family population structure (e.g., family size, the proportion of the elderly, proportion of children), and community factors (e.g., traditional market proportion, modern market proportion, transportation proportion). The results controlled the fixed effects of individuals and years. *, **, *** refer to statistically significant at 10%, 5%, and 1% respectively.

Table 4.2 Impact of trade liberalization on dietary quality

	Variable	Diversity	Ln(calorie)	Protein_share	Fat_share	SCNS
Total sample	log(tariff)	32.22***	0.67***	-0.08***	-0.17***	-0.45***
Rural sample	log(tariff)	15.98***	0.55***	-0.14***	-0.33***	-0.79***
Urban sample	log(tariff)	51.45***	-0.47*	0.09***	0.04	0.18
Urban sample	log(tariff)	-36.21	-16.91	-99.56**	-41.08*	-6.62

Source: Data are drawn from China Health and Nutrition Survey (CHNS) 1997-2011.

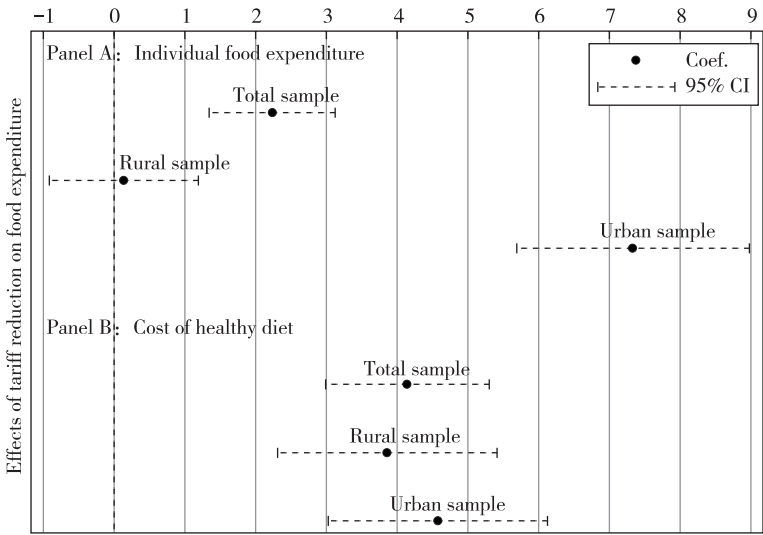
Note: Tariff = weighted tariff level at the regional level; SCNS = share of calories drawn from nonstaples. The control variables include household per capita income, food price, personal characteristics (e.g., age, gender, education level, physical activity level), family population structure (e.g., family size, proportion of elderly, proportion of children), and community factors (e.g., traditional market proportion, modern market proportion, transportation proportion). The results controlled the fixed effects of individuals and years. *, **, *** refer to statistically significant at 10%, 5%, and 1% respectively.

is also noticeably greater than that in rural areas (Figure 4.12). This is because many rural residents are more self-sufficient, and rural households are more resistant to market price changes, making them less dependent on the food market than are their urban counterparts. From the results obtained regarding dietary diversity and caloric sources, we found that reducing tariff rates has a significant negative impact on dietary diversity and daily caloric intake but that the share of calories obtained from protein, fat, and nonstaple foods can be improved. Specifically, a 10.00 percent tariff reduction will reduce dietary diversity by 11.47 percent and total calorie intake by 6.70 percent, but the share of calories obtained from protein, fat, and nonstaple foods will increase by 5.76 percent, 10.83 percent, and 16.54 percent of their average values, respectively. In addition, we found that the results obtained for rural areas are consistent with the results of the total sample but that the results for

urban areas are different. Tariff reduction has a significant positive impact on the dietary energy intake of urban residents, but the share of calories obtained by urban residents from protein gradually decreases with the liberalization of trade.

In summary, we used trade liberalization tariff data and CHNS diet-related data to find that China’s trade opening has had a significant impact on residents’ nutrition transition. Additionally, through our research, we found that China’s trade opening has increased the income of rural residents and the wages of urban residents while making agricultural production more specialized. After the reduction of customs duties, people’s preference for grains and eggs decreased, and their preference for fruits, beans (and nuts), meat, fish, and milk significantly increased. Overall, people’s food preferences shifted from grains to animal products.

Figure 4.12 Impact of trade liberalization on food expenditure



Source: Data are drawn from China Health and Nutrition Survey (CHNS) 1997-2011.

Note: Coef. = coefficient; CI = confidence interval.

4.5.2 Effect of FDI on Dietary Patterns

During the early stage of China’s reform and opening up, McDonald’s and KFC were among the first foreign catering enterprises to enter the Chinese market. Catering is the most concentrated manifestation of foreign goods and services, directly affecting people’s food consumption and health. After China’s entry into the WTO, China continuously opened its domestic market.

As a result, multinational fast-food restaurants such as KFC and McDonald’s developed and spread rapidly after entering the Chinese market. For example, about 200 to 300 McDonald’s restaurants open in China every year, with roughly 3,000 McDonald’s and nearly 6,000 KFC restaurants in Chinese cities by 2019, covering more than 1,200 cities and towns.

However, the greater the density of regional fast-food restaurants, the easier it is for residents to obtain



unhealthy fast food, which may have a negative impact on people's dietary health. Using the CHNS database and the expansion data for McDonald's and KFC stores in various regions of China, we studied the impact of the expansion of fast-food chains on residents' dietary consumption and health. We constructed the density of KFC and McDonald's stores within 10 kilometers of a given community from 1989 to 2015.

From a food consumption perspective, the expansion of McDonald's and KFC stores has increased people's calorie and fat intake and significantly increased

the probability of individuals' drinking foreign brands of soft drinks (including carbonated drinks) (Table 4.3). Both McDonald's and KFC specialize in the production and sale of fast-food, high-fat, and high-calorie foods. By exploring the impact of the density of fast-food restaurants on residents' dietary consumption, we found that the expansion of McDonald's and KFC stores has a significant positive impact on individual calorie and fat intake but has no significant impact on carbohydrate and protein intake. The more nearby McDonald's and KFC stores, the easier it is to obtain these fast foods,

Table 4.3 Impact of expansion of fast-food restaurants on dietary quality and nutritional status

Variable	Ln(calorie)	Ln(carbon water)	Ln(fat)	Ln(protein)	Soft drink	Overweight
Fast-food restaurant density (10 kilometer)	0.085**	0.045	0.228***	0.039	0.282*	0.147***

Source: Data are drawn from China Health and Nutrition Survey (CHNS) 1997-2011.

Note: The control variables include the dummy variables of gender, years of education, age, disease history, smoking behavior, drinking behavior, family income, living status, and occupation type at the individual level as well as per capita gross domestic product, urbanization rate, and other time-varying macroeconomic factors at the urban level. The results control the fixed effects of cities and years. *, **, *** refer to statistically significant at 10%, 5%, and 1% respectively.

thus increasing the intake of substances with higher fat content in these foods.⁶

From a dietary health perspective, expanding McDonald's and KFC stores has significantly increased the probability of individuals' becoming overweight. The entry of FDI such as through McDonald's and KFC can increase people's intake of high-fat and high-calorie foods and carbonated drinks, but excessive intake of these unhealthy fast foods will have a negative impact on people's health. We used the metric of being overweight or not as a measure of health in our study, with the research results showing that the greater the density

of KFC and McDonald's stores within 10 kilometers of a given community, the higher is the probability of individual obesity. By distributing the density of KFC and McDonald's stores within a 10 kilometer radius, we found that the probability of overweight people being present in the first quantile community was 10.2 percentage points higher than that of people in the third quantile community. Our research results also showed that this impact varied according to people's education levels and gender. The expansion of fast-food restaurants has a more obvious negative impact on people with lower education levels and has a greater negative impact on men than on women.

Through existing research, we have found that FDI in the catering industry has increased people's intake of unhealthy foods and has had adverse effects on residents' dietary health. However, in spite of these findings, we are not opposed to globalization because it also brings many benefits to people, such as an increase in the diversity of consumer goods not covered in this study and the low prices generated by the competitive effect. Nonetheless, we emphasize the need for people to pay attention to the consumption of unhealthy food by residents and the impact of unhealthy food such as fast

⁶The regression model is $y_{it} = \beta Food_{c,t-1}^{10km} + \gamma X_{it} + \lambda_{pt} + \lambda_c + \varepsilon_{it}$, where i and t represent individuals and years and c and p represent communities and cities, respectively. $Food_{c,t-1}^{10km}$ is the core explanatory variable, indicating the logarithm of the number of McDonald's and KFC stores within 10 kilometers of the community. The core explanatory variable is mainly obtained through household survey. It can represent the index of individual i 's dietary intake in year t (including calorie, carbohydrate, oil, and protein intake and soft drink drinking frequency) and the index of dietary health (whether overweight). The data were obtained from CHNS. X_{it} refers to the control at the individual level, including the dummy variables of gender, years of education, age, disease history, smoking behavior, drinking behavior, family income, living status, and occupation type. λ_{pt} refers to the control variables at the urban level, including gross domestic product per capita, urbanization rate, and other time-varying macroeconomic factors at the urban level. The control variable data mainly come from CHNS.



food on people's dietary health through global channels.

4.6 How Trade and FDI Affect the Environment through Diet

In recent decades, the food processing industry has developed rapidly, resulting in a closer interaction between trade, diet, and the ecological environment (Friel 2020). Trade and FDI have facilitated dietary transitions in many countries; altered food consumption patterns in various regions; increased the demand for processed, semicooked, and animal food; and promoted the growth of the food industry. The transition in dietary consumption and production processes not only affects residents' nutritional and health status but also has an impact on environmental sustainability (Kearney 2010; Poore and Nemecek 2018).

First, trade and FDI influence the environment by altering food consumption patterns. Research indicates that the food system contributes 1/3 of global anthropogenic greenhouse gas (GhG) emissions, more than 23.00 percent of active nitrogen emissions, around 70.00 percent of surface water and groundwater, and 90.00 percent of phosphate rock (Crippa et al. 2021; Oita et al. 2016; Hoekstra and Mekonnen 2012; Rosemarin 2004). By replacing 50.00 percent of meat and dairy products with vegetables, fruits, and cereal, global food-related GhG emissions can be reduced by 29.00 to 70.00 percent by 2050 (Springmann et al. 2018). Conversely, if the global dietary structure continues to shift toward animal protein consumption, GhG emissions from crop and livestock production will increase by 32.00 percent between 2009 and 2050, exacerbating the environmental pressures created by the global food system (Tilman and Clark 2014). Numerous country-specific studies have found that dietary transitions significantly affect the environment. Ritchie and colleagues (2018), for example, found that different countries' recommended daily diets had large differences in their carbon dioxide equivalents. If China's food consumption pattern in 2015 were adjusted according to its dietary guidelines, its nitrogen, phosphorus, and carbon footprints would reduce by 36.00 percent, 22.00 percent, and 29.00 percent, respectively, while its water footprint would increase by 3.00 percent (Wang et al. 2020).

Second, trade and FDI can affect the environment

by altering food production processes. They improve the supply capacity of modern agricultural production factors such as fertilizers, pesticides, and machinery in developing countries, promoting a shift in their agricultural production from traditional to modern production modes that are heavily dependent on fossil fuels. This agricultural production mode transition increases productivity but also raises the level of water, soil, and air pollution. Trade and FDI also facilitate the continued development of China's food processing industry, expanding the food industrial chain from production to consumption and increasing environmental pollution related to the food system while simultaneously creating employment opportunities and income. According to the China Environmental Statistics Yearbook 2021, emissions of chemical oxygen demand and ammonia nitrogen from the food processing and manufacturing industry are 90 to 110 times that of the traditional agriculture sector. Trade and FDI have also hastened the conversion of tropical forests into farmland, further increasing the level of GhG emissions.

4.7 Suggestions for Using Trade and FDI to Improve Dietary Quality in Developing Countries

International trade and FDI have a significant impact on the dietary structure and nutrition transition of developing countries. International trade and investment can improve the quality of diets in these countries by reducing dietary costs, diversifying food choices, and altering the sources of calories. Therefore, improving dietary nutrition should be included in the agenda for WTO negotiations, and the direction of FDI should be guided toward enhancing the dietary quality of developing countries through trade and investment. Based on our research, we propose the following policy recommendations.

4.7.1 Guide the Investment Direction of FDI in China to Improve the National Dietary and Nutritional Status

First, we should increase the proportion and scale of China's agricultural FDI in general, aiming to improve the national diet's nutritional status by encouraging



agricultural development, reducing dietary costs, enhancing dietary diversity, and optimizing calorie sources.

Second, we should encourage the direction of FDI toward enhancing dietary nutrition status while promoting openness and convenience for FDI in the food industry. With the goal of improving the quality of diets, lowering dietary costs, and enhancing dietary diversity and calorie sources, we can further liberalize restrictions around FDI in the food industry by reducing qualification requirements, equity ratios, business scopes, and investment methods. Additionally, we can guide FDI toward agriculture, food processing, and related industries that enhance the nutritional status of the national diet, promote the agglomeration of FDI in high-tech and high-end catering industries, and elevate cooperation levels with foreign-funded enterprises in the catering industry. We can also utilize successful institutional innovations achieved in FDI promotion, protection, management, and other aspects of free trade zones to strengthen the performance and leading functions of various open platforms, extend and expand the industrial chain, enhance industrial supporting capacity, and foster competitive food and health industrial clusters.

Last, we should promote the refinement and implementation of an FDI review system and regulatory system in the catering sector. The internationally accepted practice of FDI review and supervision systems can help in a number of ways. It can provide institutional arrangements for directing FDI, carry out key tasks, implement in-process and postevent supervision measures in the dietary field, preclude or mitigate the negative effects of FDI on attempts to improve national dietary and nutritional status, and provide institutional guarantees for developing countries to further improve their national dietary and nutritional status.

4.7.2 Incorporate the Goal of Improving Dietary Nutrition into WTO Negotiations and Make Full Use of Two Markets and Two Resources to Safeguard China's National Food Security

First, WTO member countries should reduce bans or restrictions on the export of agricultural products

and food. In the food industry, including the sectors for grains, vegetables, fruits, beans (and nuts), meat (including poultry), milk (including dairy products), eggs, and fish (including all aquatic products), members should pledge not to implement prohibitions or restrictions on the export of agricultural products and foods that are inconsistent with relevant WTO provisions. Members should also avoid politicizing trade of agricultural products and prevent overreactions to agricultural product and food trade events in order to successfully expand dietary sources for developing countries.

Second, necessary assistance should be provided to developing countries with poor levels of dietary nutrition. Technical and financial aid related to agriculture and food industries should be offered to developing countries with poor dietary nutrition that are net importers of agricultural products to help them to develop their own dietary industries. Members with stocks of agricultural products should release these stocks to developing countries with poor dietary nutrition through the international market in a manner that is consistent with WTO rules. This would in turn reduce dietary costs and enhance dietary diversity and calorie sources for developing countries.

Third, the most-favored nation treatment principle should be promoted while also implementing the Generalized System of Preferences. Promoting both of these principles in the food trade industry can enhance bilateral trade and trade openness, improve food quality, increase the income of developing countries, and further promote the nutritional status of national diets in developing countries.

References

- Atkin, D, Trade, taste and nutrition in India. *American Economic Review*, 2013, 103 (5): 1629-1663.
- Azzam, A., Is the world converging to a 'Western diet'? *Public health nutrition*, 2021, 24(2): 309-317.
- Baker, P., Friel, S., Schram, A., Labonte, R., Trade and investment liberalization, food systems change and highly processed food consumption: a natural experiment contrasting the soft-drink markets of Peru and Bolivia. *Globalization and Health*, 2016, 12(1): 24.
- Baylis, K., Fan, L., Nogueira, L., Agricultural Market Liberalization and Household Food Security in Rural China By relaxing the grains quota, *American Journal of Agricultural Economics*, 2019, 101(1): 250-269.



- Behrman, J., Doelalikar, A., Will developing country nutrition improve with income-a case study for rural South India. *Journal of Political Economics*, 1987, 95 (3): 492-507.
- Bennett A J, Bending G D, Chandler D, Hilton S, Mills P. Meeting the demand for crop production: the challenge of yield decline in crops grown in short rotations[J]. *Biological reviews*, 2012, 87(1): 52-71.
- Cassels, S., Overweight in the Pacific: links between foreign dependence, global food trade, and obesity in the Federated States of Micronesia. *Globalization and Health*, 2006, 2(1): 1-8.
- Chavarría D N, Verdenelli R A, Serri D L, Restovich S B, Andriulo A E, Meriles J M, Vargas-Gil S. Effect of cover crops on microbial community structure and related enzyme activities and macronutrient availability[J]. *European journal of soil biology*, 2016, 76: 74-82.
- Clark, S.E., Hawkes, C., Murphy, S.M.E., et al.. Exporting obesity: U.S. farm and trade policy and the transformation of the Mexican consumer food environment. *International journal of occupational and environmental health*, 2012, 18(1): 53-64.
- Crippa, M., Solazzo, E., Guizzardi, D. et al. Food systems are responsible for a third of global anthropogenic GHG emissions. *Nat Food* 2021, 2: 198-209.
- Cui, S., Shi, Y., Malik, A., Lenzen, M., Gao, B., Huang, W., A hybrid method for quantifying China's nitrogen footprint during urbanisation from 1990 to 2009. *Environ. Int.*, 2016, 97: 137-145.
- De Soysa I., De Soysa AK., Do Globalization & Free Markets Drive Obesity Among Children and Youth? An Empirical Analysis, 1990-2013. *Int Interact*, 2017.
- [13] Dithmer J., Abdulai, A., Does trade openness contribute to food security? A dynamic panel analysis, *Food Policy*, 2017, 69: 218-230.
- Djokoto JG., Effects of foreign direct investment inflows into agriculture on food security in Ghana. *J Econ Sustain Dev*, 2012, 3(2): 81-92.
- Emma C. S., Mabaya, E., von Cramon-Taubadel, S., Barrett, C. B., Spatial Price Adjustment with and without Trade, *OXFORD BULLETIN OF ECONOMICS AND STATISTICS*, 2012, 74, 3 : 453-469
- Friel, S., Schram, A., Townsend, B., The nexus between international trade, food systems, malnutrition and climate change, *Nature Food*, 2020, 1: 51-58.
- Giuntella, O., Rieger, M., Rotunno, L., Weight gains from trade in foods: Evidence from Mexico. *Journal of International Economics*, 2020, 122: 103277.
- Hawkes C., Uneven dietary development: linking the policies and processes of globalization with the nutrition transition, obesity and diet-related chronic diseases. *Globalization and Health*, 2006, 2(1): 1-18.
- Hoekstra, A., Mekonnen, M.M., The water footprint of humanity. *Proc. Natl. Acad. Sci*, 2012, 109 (9), 3232-3237.
- Huang, Y., Tian, X., Food accessibility, diversity of agricultural production, and dietary pattern in rural China. *Food Policy*, 2019, 84: 92-102.
- Jenkins, J.C., Scanlan, S.J. Food Security in Less Developed Countries, 1970 to 1990. *Am. Sociol. Rev*, 2001, 66: 718-744.
- Jensen, T.R., Miller, N.H., A Revealed Preference Approach to Measuring Hunger and Undernutrition. *NBER Working Paper* 16555, 2010
- Jones, A.D., Shrinivas, A., Bezner-Kerr, R., Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. *Food Policy*, 2014, 46 (3): 1-12.
- Kearney, J., Food consumption trends and drivers. *Philos. Trans. Royal Soc.*, 2010, 365 (1554), 2793-2807.
- Krivosos, E., Kuhn, L., Trade and dietary diversity in Eastern Europe and Central Asia. *Food Policy*, 2019, 88: 101767.
- Kummu, M., Kinnunen, P., Lehtikainen, E., Porkk, M., Queiroz, C., Roos, E., Troelle, M., Weil, C., Interplay of trade and food system resilience: Gains on supply diversity over time at the cost of trade interdependency, *Global Food Security*, 2020, 24 : 100360.
- Law, C., Unintended consequence of trade on regional dietary patterns in rural India, *World Development*, 2019, 113: 277-293.
- Lin, J., Hu, Y., Cui, S., Kang, J., Xu, L., Carbon footprints of food production in China (1979-2009). *Journal of Cleaner Production*, 2015, 90: 97-103
- Lopez A M, Loopstra R, McKee M, et al. Is trade liberalisation a vector for the spread of sugar-sweetened beverages? A cross-national longitudinal analysis of 44 low-and middle-income countries, *Social science & medicine*, 2017, 172: 21-27.
- Maystre, N., Olivier, J., Thoenig, M., Verdier, T., Product-based cultural change: Is the village global? *Journal of International Economics*, 2014, 92(2): 212-230.
- Meng, X., Gong, X., Wang, Y., Impact of income growth and economic reform on nutrition availability in urban China: 1986-2000. *Economic Development and Cultural Change*, 2009, 57 (2): 261-295.
- Mihalache-O'keef, A., Li, Q., Modernization vs. dependency revisited: effects of foreign direct investment on food security in less developed Countries1. *Int Stud Q.* 2011, 55(1): 71-93.
- Miljkovic, D., Shaik, S., Miranda, S., Barabanov, N., Liogier, A., Globalisation and obesity. *World Economy*. 2015, 38 (8), 1278-1294.
- Montolalu M H, Ekananda M, Dartanto T, et al. The Analysis of Trade Liberalization and Nutrition Intake for



- Improving Food Security across Districts in Indonesia[J]. *Sustainability*, 2022, 14(6): 3291.
- Ogundari, K., Abdulai, A., Examining the heterogeneity in calorie-income elasticities: a meta-analysis. *Food Policy*, 2013, 40: 119-128.
- Oita, A., Malik, A., Kanemoto, K., Geschke, A., Nishijima, S., Lenzen, M., Substantial nitrogen pollution embedded in international trade. *Nat. Geosci.* 2016, 9 (2), 111-115.
- Poore, J., Nemecek, T., Reducing food's environmental impacts through producers and consumers. *Science* 360, 2018, 987-992. <https://doi.org/10.1126/science.aag0216>.
- Popkin, B. M., Adair, L.S., Ng, S.W., Global nutrition transition and the pandemic of obesity in developing countries. *Nutrition Reviews*, 2012, 70(1): 3-21.
- Reardon T, Tschirley D, Liverpool-Tasie L S O, et al., The processed food revolution in African food systems and the double burden of malnutrition. *Global food security*, 2021, 28: 100466.
- Ritchie, H., Reay, D.S., Higgins, P., The impact of global dietary guidelines on climate change. *Globl. Environ. Chang*, 2018, 49: 46-55.
- Rosemarin, A., In a fix: the precarious geopolitics of phosphorous. *Cent. Sci. Environ.* 2004, 30, 27-31.
- Schram, A., Labonte, R., Baker, P., Friel, S., Reeves, A., Stuckler, D., The role of trade and investment liberalization in the sugar-sweetened carbonated beverages market: a natural experiment contrasting Vietnam and the Philippines. *Globalization and health*, 2015, 11:41.
- Sibhatu, K.T., Krishna, V.V., and Qaim, M., Production diversity and dietary diversity in smallholder farm households. *Proceedings of the National Academy of Science*, 2015, 112 (34):10657-10662.
- Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L., et al., Options for keeping the food system within environmental limits. *Nature*, 2018, 562 (7728), 519-525.
- Stuckler D, McKee M, Ebrahim S, Basu S., Manufacturing epidemics: the role of global producers in increased consumption of unhealthy commodities including processed foods, alcohol, and tobacco. *PLoS Med.* 2012, 9(6): e1001235.
- Subramanian, S., and A. Deaton., The demand for food and calories. *Journal of Political Economy*, 1996, 104 (1):133-162.
- Thow, A. M., Trade liberalisation and the nutrition transition: mapping the pathways for public health nutritionists. *Pub. Health Nutr*, 2009, 12, 2150-2158 .
- Tian, X. and X. Yu., Using Semiparametric Models to Study Nutrition Improvement and Dietary Change with Different Indices: The Case of China. *Food Policy*, 2015, 53: 67-81.
- Tilman, D., Clark, M., Global diets link environmental sustainability and human health. *Nature*, 2014, 515 (7528), 518-522.
- UNCTAD.(Aarious years). *World Investment Report*. New York, NY: The United Nations
- Vassilakopoulou P, Hustad E., Bridging digital divides: a literature review and research agenda for information systems research. *Information Systems Frontiers*, 2021: 1-15.
- Vogli R D, Kouvonen A, Elovainio M, et al., Economic globalization, inequality and body mass index: a cross-national analysis of 127 countries. *Critical Public Health*, 2014, 24(1): 7-21.
- Volkow N D, Wang G J, Baler R D., Reward, dopamine and the control of food intake: implications for obesity. *Trends in cognitive sciences*, 2011, 15(1): 37-46.
- Wang, L., B. Gao, Y. Hu, W. Huang, S. Cui, Environmental effects of sustainability-oriented diet transition in China, *Resources, Conservation & Recycling*, 2020, 158:104802
- Wimberley DW, Bello R., Effects of foreign investment, exports, and economic growth on third world food consumption. *Soc Forces*. 1992, 70(4):895-921.
- Wimberley DW., Transnational corporate investment and food the third world: a cross-National Analysis. *Rural Sociol.* 1991, 56(3):406-3
- Zhai Tao, Wu Ling. Research on the development trend and revitalization strategy of China's soybean industry from an open perspective [J]. *Soybean Science*, 2020, 39 (03): 472-478(in Chinese)
- Lin Dayan, Xu Lei, Zhu Jing, Quan Xiaoyun. A study on the impact and path of trade liberalization on China's food consumption inequality -- based on the test of multiple and multiple intermediary effects model[J]. *Issues in Agricultural Economy*, 2021, (03): 114-125(in Chinese)
- Tang Bi, Li Miao chen. Research on China's soybean import stability and industrial development in the post-epidemic era [J]. *Agricultural Economic Issues*, 2022 (10): 123-132(in Chinese)
- Zhao Yinyu, Zheng Zhihao. China's soybean and soybean oil demand: an empirical analysis based on the SDAIDS model [J]. *China Rural Economy*, 2015 (11): 15-28(in Chinese)



Chapter 5

Consumer-side Interventions: Enabling Sustainable and Healthy Food Choices

Jingjing Wang,^{1,2} Fuli Tan,^{1,2} Xin Zhang,^{1,2} Wen Lin,³ Xiaotian Fu,⁴ Haijun Zhao^{4,5}

1. Academy of Global Food Economics and Policy, China Agricultural University

2. College of Economics and Management, China Agricultural University

3. China Academy of Rural Development, Zhejiang University

4. Food and Natural Resources Program, World Resources Institute

5. The Food and Land Use Coalition

Key Findings

- Changes in food production and supply chains alone are insufficient to create a sustainable and healthy dietary transition. Currently, effective measures for supporting this transformation are lacking.
- The food consumption behavior of consumers is the primary factor affecting the healthiness and sustainability of their diets, and it can be influenced by various factors such as information, economy, policy, and culture. Therefore, effective intervention programs and policies should be formulated based on specific objectives and goals to overcome obstacles to transforming dietary behavior.
- Various intervention strategies (i.e., information intervention, behavioral intervention, economic incentives, and support policies) can be employed to promote the adoption of sustainable and nutritious diets among

consumers. Interventions aimed at providing information can enhance the knowledge and understanding of nutrition and sustainability of consumers, leading to changes in demand. Through the manipulation of the food environment, behavioral interventions can directly affect consumer behavior, thereby serving as a crucial factor in the attainment of sustainable and healthy diet transformation. However, the efficacy of economic incentives for fostering sustainable and healthy dietary patterns remains uncertain.

- Future research should focus on the applicability and effectiveness of intervention programs targeting specific groups and consumption scenarios.



Policy recommendations

- Promoting food education for all and cultivating the concept of sustainable and healthy diets should be a top priority. Establishing food education programs in schools, providing professional nutritionists in communities (villages), and using information and communications technology for public awareness campaigns can be effective tools to bridge the “last mile” gap in nutrition knowledge and guide consumers in forming healthy dietary habits.
- Creating a healthy and enabling food environment is critical in promoting sustainable and healthy dietary habits among consumers. Appropriate industry regulations can foster an industry that adheres to standardized labeling, certification, and general standards for the food industry. Additionally, behavioral interventions can guide and enable shifts in consumer choices toward healthy and sustainable food.
- Increasing policy coordination and incentives for a healthy and sustainable food industry is critical. A multisectoral collaboration framework should be created to improve the food business chain toward health and sustainability. Improved laws and regulations

and clear guidance and oversight roles of government departments could help this system. Financial policies, tax subsidies, and other measures should encourage the production and consumption of sustainable and healthy foods to meet the nutritional needs of vulnerable groups. Providing training and encouraging sustainable procurement and central kitchens can help administrators understand and implement sustainable and healthy diets.

- Implementing a national nutrition improvement plan through targeted interventions is essential. To implement precise interventions, policymakers should design targeted dietary intervention strategies that consider differences in regions, demographic groups, and consumption scenarios. Food assistance programs that meet the food needs of low-income urban populations should be considered.



5.1 Introduction

A suboptimal diet is the primary risk factor for malnutrition and diet-related noncommunicable diseases in China. Inadequate consumption of nutrient-dense foods (i.e., whole grains, dark leafy vegetables, fruits, dairy products, fish, shellfish, and soybeans) along with unsustainable dietary practices (i.e., excessive consumption of meat and ultra-processed foods, as well as food waste) negatively affect the well-being of individuals and impede sustainable development, thereby imposing a strain on the economic growth of the nation. There is an urgent need for a “diet revolution” to promote sustainable and healthy diets in China.

In contrast to nutrition-focused healthy diets, sustainable and healthy diets consider the carrying capacity of the ecological environment while simultaneously fulfilling the nutritional and health requirements of individuals. Healthy and sustainable diets of this nature exhibit positive externalities for the society and others by fostering good health, decreasing medical expenses, safeguarding resources and the environment, and alleviating the effects of climate change. Nevertheless, the general public’s comprehension of sustainable and healthy diets and intrinsic drive to embrace such diets remain insufficient.

As public awareness of diet-related burdens in healthcare costs and environmental consequences increases, how to identify the pathways to promote sustainable and healthy diets has emerged as a crucial public policy concern. The dietary structure of consumers depends on various factors including cognitive processes, cultural practices, and habitual tendencies as well as the market, food environment, and policy environment within which they are situated. Relying solely on market mechanisms is inadequate to address the problem of suboptimal dietary intake.

The attainment of a sustainable and healthy dietary transformation necessitates a collaborative endeavor involving food production techniques, consumption systems, and market mechanisms, with the alteration of the consumer aspect being a pivotal factor. The decision-making role of consumers in dietary behavior is crucial because their food cognition and preferences are critical determinants that influence their dietary choices. Although increasing the supply of healthy food can increase the

consumption of nutritious food, studies have established that differences in consumer demand are the main driver of nutritional inequalities among families of different income groups, with an equal supply contributing to no more than 10 percent of the nutritional inequalities (Allcott et al. 2019a). Furthermore, demand changes serve as a main driving force in the transformation of the food industry chain. Changes in consumer demand for food can affect food supply through the market, prompting adjustments and transformations in food production methods, structures, processing, retailing, and marketing. The shift toward a sustainable and health-driven diet by consumers serves as an extrinsic motivator for the food industry’s transformation.

Promoting sustainable and healthy food choices among consumers remains a significant challenge in many countries seeking dietary transformation. Various intervention methods (i.e., education and promotional campaigns, behavioral intervention, economic incentives, and industry standards regulations) have been employed by governments and companies in some countries to guide consumers to change their dietary behaviors. However, most existing intervention studies have focused solely on healthy foods, with only a limited number addressing the sustainable characteristics of food. Therefore, it remains a pressing matter to investigate scientific interventions that encourage sustainable and healthy eating choices among consumers.

With the rapid transformation of consumers’ dietary structures and the emergence of new food consumption and supply methods in the new era, it is important to systematically examine the impact of different intervention methods on the sustainable and healthy dietary choices of consumers based on China’s social culture and dietary status. In this chapter, we analyze the constraints and driving factors of the sustainable and healthy dietary choices of consumers and discuss the impact paths and effects of various intervention strategies on consumer behavior. We also examine the effectiveness of dietary intervention programs and policy design schemes and offer suggestions for prioritizing and optimizing nutrition education, economic incentives, market environment, and identifying targeted population intervention.

The remainder of this chapter is organized as follows. Section 5.2 evaluates drivers and barriers for consumers’ dietary shifts. Section 5.3 discusses intervention strategies to facilitate shifts in consumers’



food choices. Section 5.4 presents strategies for implementing different types of interventions. Finally, Section 5.5 discusses the conclusions and recommendations of the study.

5.2 Drivers and Barriers for Consumers' Dietary Shifts

A consensus has been reached in previous research on the characteristics of sustainable and healthy diets, which include reducing the overconsumption of food beyond nutritional needs, decreasing food waste, consuming less energy-dense but nutrient-poor ultra-processed foods, and shifting toward a diet with a larger proportion of plant-based foods and fewer animal-based foods (Friel et al. 2014; Willett et al. 2019). As discussed in the previous chapters of this report, a healthy and sustainable diet should consider food quantity and quality as well as environmental impact. To achieve a healthy and sustainable diet in China, recommendations are to decrease the excessive consumption of meat by replacing it with low-carbon alternative proteins, increase the intake of plant-based foods (i.e., fruits and vegetables), and ensure dietary diversity. Effective intervention strategies are crucial for promoting sustainable and healthy food choices because consumer behavior change is constrained by individual cognition, consumption habits, and food supply.

5.2.1 Barriers to Shifting Toward Sustainable and Healthy Diets

Insufficient awareness among consumers regarding sustainable and healthy diets hinders the transition of behavior. Although most consumers recognize the impact of food choices on their health, they lack knowledge of the environmental impact of certain foods (e.g., red meat) (Hartmann and Siegrist 2017; Ronto et al. 2022). The health literacy¹ of Chinese consumers is gradually improving, with an average level of 25.4

¹Health literacy refers to the ability of individuals to access and understand basic health information and services and to use the information and services to make sound decisions to maintain and promote their health. According to "Health Literacy of Chinese Citizens—Basic Knowledge and Skills (Trial)," health literacy is divided into three aspects, namely, basic health knowledge and concept literacy, healthy lifestyle and behavior literacy, and basic skill literacy.

percent among residents in 2021; however, it remains low, particularly in rural areas.² Chinese consumers are highly concerned about food safety and health; most of them lack knowledge about the environmental impact of food, and only 40 percent of consumers understand the meaning of sustainable food labels (Gao et al. 2020).

Consumer habits impose constraints on transformation. The long-term dietary choices of consumers can affect their acceptance of alternatives. For example, consumers' desire for the dietary pleasures of "meat eating" may lead them to reject plant-based alternatives (Wang and Scrimgeour 2021). Limited cooking skills (Ronto et al. 2022) and varying preferences for food taste and appearance also influence dietary behavior (Van Kleef et al. 2014).

Furthermore, the limited supply of sustainable and healthy foods hinders the transition toward better dietary habits. Price of foods remains one of the biggest factors influencing consumption, particularly for consumers in rural areas and those with low incomes, whose purchasing decisions are more likely to be determined by price. About one-sixth of the Chinese population (230 million people) cannot afford a diet that is healthy according to Chinese Dietary Guidelines (Herforth et al. 2022). Sustainable and healthy foods such as organic products and plant-based meats are relatively expensive, making them less affordable for many consumers (Aschemann-Witzel and Zielke 2017; Bryant and Barnett 2018).

Additionally, the lack of access to convenient, sustainable, and healthy foods can hinder dietary behavior change (de Boer and Aiking 2019). With the acceleration of the pace of life, convenience has become a priority for consumers, particularly young ones who prefer takeout and dining out, which may lead to an imbalanced diet with fewer vegetable servings and excessive intake of energy and fat.

5.2.2 Categories of Consumer-side Interventions for Dietary Transformation

Information asymmetry and potential externalities of food consumption necessitate interventions to enhance the dietary choices of residents. Consumers' cognitive biases and bounded rationality with respect

²http://www.gov.cn/xinwen/2022-06/08/content_5694585.htm.

to sustainable and healthy diets may lead to an underestimation of the personal benefits associated with such diets. Consequently, the dietary choices of individuals can negatively affect their personal health and impede their long-term growth (Allcott et al. 2019; Cadario and Chandon 2019). The consumption of sustainable and healthy foods has positive externalities such as mitigating the prevalence of diet-related illnesses and reducing healthcare expenses while alleviating resource and environmental constraints.

Effective interventions can address various obstacles to sustainable and healthy food consumption such as information asymmetry and externalities. Information interventions can effectively address situations in which consumers lack complete information and improve their cognition. Providing consumers with food-related nutrition, health, and sustainability information (such as labels) and promoting nutrition, health, and sustainable values and social norms can improve consumer awareness, prompt them to choose healthier and sustainable foods, and reduce food waste (Gonçalves et al. 2021; Grundy et al. 2022; Wang et al. 2020). Economic interventions such as taxes and subsidies can internalize externalities and solve market failures. Taxing goods that produce negative externalities (i.e., tobacco, alcohol, and sugar-sweetened beverages) can reduce consumption and increase social welfare

(Allcott et al. 2019b). Subsidies for healthy foods have a greater impact on food consumption than do taxes on unhealthy foods (Afshin et al. 2017). Behavioral nudging strategies can enhance the convenience and accessibility of healthy foods, reshape the food environment, and promote changes in consumers’ dietary behavior.³ Providing reminders, changing default options, and setting goal commitments are often used to help consumers choose sustainable and healthy foods (Hendren and Logomarsino 2017; Metcalfe et al. 2020).

The promotion of sustainable and healthy food consumption by consumers can be achieved through various intervention measures, as shown in Table 5.1. These measures can be classified into four categories based on their underlying reasons and mechanisms: information interventions, behavioral interventions, economic incentives, and supportive policies.

³The behavioral intervention strategy (nudge) aims to change people’s behavior by influencing the way they make choices through specific designs and strategies rather than mandating or limiting choices. This approach typically utilizes inherent biases in human behavior, such as cognitive dissonance, herd mentality, and primacy effect, to achieve the desired behavioral change. Behavioral intervention strategies have become one of the effective methods adopted by institutions such as governments, businesses, and nonprofit organizations and have been widely applied in many fields.

Table 5.1 Categories of interventions

Reasons for intervention	Information interventions	Behavioral interventions	Economic incentives	Supportive policies
Externalities	–	Nudge	Tax or subsidies, market incentives	Social assistance, trade policy
Information asymmetry	Labels, nutrition education	Information nudge	–	–
Bounded rationality	–	Convenience-oriented nudge	–	Regulations

Source: Carlsson et al. (2022).
Note: – = not applicable.

5.3 Intervention Strategies to Facilitate Shifts in Consumer Food Choices

In this section, we discuss the crucial intervention strategies that can drive changes in consumer food choices, which are categorized into four aspects: information interventions, behavioral interventions,

economic incentives, and supporting policies.

5.3.1 Information Interventions

Information interventions primarily affect individuals’ attitudes and intentions by providing relevant information. Strategies for information interventions that



influence an individual's food choices include educating consumers, providing labeling knowledge, counseling, and implementing self-monitoring or multifactor combination interventions. Moreover, social culture and norms contribute to consumers' understanding of the effects of food consumption on health and the environment.

5.3.1.1 Food Labeling

Food labeling takes various forms including nutrition labeling, front-of-pack (FOP) labeling, health claims, food certification labels, and carbon labels. These labels can provide consumers with essential information about food nutrition and sustainability both promptly and effortlessly.

Although most foods are labeled with nutritional facts, a significant number of Chinese consumers (70 percent) ignore such labels when shopping (Liu et al. 2015). However, foreign practices suggest that FOP labeling, which displays simplified nutritional information on the front side of food packaging, can increase the likelihood of consumers' choosing healthy foods (Zhu et al. 2015). Examples of effective FOP labeling systems include the UK's traffic light system, Sweden's green "Keyhole" sign, and Chile's "Stop-sign" (Cabrera et al. 2018). Nutrient content and comparative health claims can also provide nutrition and health information to consumers, aiding them in making informed choices (Ballco and Gracia 2022). Although China's "General Rules for Nutritional Labeling of Prepackaged Foods" specifies the nutritional content and claims of food, FOP labeling has not yet been developed.

Fewer options are available for sustainability labels than for nutrition labels. The two primary types of sustainability labels include certification and carbon labels. Certification labels are awarded to food produced sustainably, such as organic food certification labels, which can help consumers identify specific food information. Chinese are willing to pay more for organic food certification labels, but they lack trust of labels provided by domestic certification agencies (Wang et al. 2020). Carbon labeling provides information about carbon emissions on food labels. Recent studies have demonstrated that carbon footprints labeling interventions can reduce the probability of British consumers' choosing high-carbon-footprint foods by

2.7 percent and lower the average carbon emissions per meal by 4.3 percent (Lohmann et al. 2022). However, in China, research on food carbon labeling has mainly focused on consumer willingness to pay, and few studies have focused on actual behavior (Xu and Lin 2022; Zhao et al. 2018).

5.3.1.2 Nutrition and Sustainability Education

Nutrition education is a valuable tool for improving consumer health and nutrition status. Its purpose is to disseminate nutrition science knowledge, enabling people to acquire food and nutrition knowledge and skills to make healthier food choices. A six-month nutrition education intervention in Chinese schools significantly improved nutrition knowledge and cognition of the relationship between food and health in the intervention group. Furthermore, the daily vegetable intake of students in the intervention group was 15 percent higher than that of students in the control group (Wang et al. 2015). Similar interventions in universities or communities in other countries have significantly increased vegetable intake in the intervention groups (Ko et al. 2016; Metcalfe et al. 2020). With the help of network technology (i.e., tailor-made text messages, emails, and TV cooking shows), consumers' intake of vegetables and fruits has increased while processed meat intake has decreased (Ghammachi et al. 2022). Governments' public awareness campaigns promoting healthy eating, such as Japan's Food Education Promotion Program, have successfully raised public health awareness. Cooking classes in schools have also been successful in countries such as Denmark and the United Kingdom (Chen et al. 2012).

The utilization of modern technologies, including big data, applications, and games, has proven to be an effective strategy for promoting food literacy. For instance, physical activities or video games can enhance the nutritional cognition and attitude of children, increasing vegetable and fruit intake (Chow et al. 2020). Similarly, the use of apps to standardize the ecological score (or eco-score) of different foods is an effective way to promote food sustainability, particularly because it can be difficult for consumers to evaluate the environmental impact of food (Weber 2021).



5.3.1.3 Social Norms and Culture

Social norms serve as an important external reference and implicit code for individuals' dietary behavior, allowing them to use others' eating behavior in a specific environment as a guide to determine the appropriateness of their own behavior (Herman et al. 2003). Studies have confirmed that portraying the positive social value of plant-based diets to consumers significantly increases their consumption of vegetables and fruits while reducing their consumption of processed meat (Gonçalves et al. 2021; Ronto et al. 2022). Social media and advertisements play a crucial role in promoting sustainable and healthy dietary values. For example, the amount of time spent watching food advertisements is positively correlated with children's calorie and snack intakes (Kelly et al. 2019). Furthermore, promoting online food platforms, social networks, and public praise can significantly affect food purchase decisions of Chinese consumers (Qi and Ploeger 2021). The dietary behavior of young people is influenced by their peers' dietary cognition (Zhang et al. 2023). Therefore, interventions targeting media platforms, peers, and key opinion leaders in the community can help establish sustainable and healthy dietary values and

promote group-level sustainable diet behavior changes.

Culture influences the psychological perceptions, attitudes, and habits of consumers, ultimately shaping their food consumption behavior (Roudsari et al. 2017). The diversity of Chinese culture has contributed to unique regional dietary forms, including traditional Chinese medicine beliefs, long-standing dietary cultures such as the same origin of medicine and food, collectivist attitudes, "banquet culture," and many food-related festivals that have a significant effect on Chinese dietary behavior change (Woetzel 2019). Chinese culture is often described as more collectivist than the cultures of other industrialized nations, and research has shown that Chinese people are more likely to follow collective dietary norms, with their food purchases influenced by recommendations from acquaintances or related reference groups (i.e., online review communities) (Qi and Ploeger 2021; Attwood et al. 2023). The cultural concept of "balanced diet" in traditional Chinese medicine is considered important to the formation of social norms of reasonable diet, which may provide a better entry point for future dietary interventions (Chen et al. 2022).

Case 5.1 Information Intervention Boosts Healthy and Sustainable Dietary Choices of Chinese Urban Residents

Source: Kevin Chen, Luyun Yu, Wen Lin (corresponding author), David Ortega. 2022. Information framing effects on diet choices among Chinese urban residents. Working paper. Zhejiang University-IFPRI Center for International Development Studies

This study investigates the impact of eight information interventions on the health and sustainable dietary consumption behaviors of Chinese urban residents. It compares and analyzes the effectiveness of these interventions among different groups to identify effective methods for information intervention and provides a scientific reference for nutrition and health policies. Information intervention measures were designed based on information content expression, sources, and platforms, as shown in the table below. The research methods included network questionnaire surveys, random grouping, and dietary choice experiments. Consumers participating in the survey were randomly divided into nine groups: eight treatment groups with varying information interventions and one control group without any information intervention. Based on an empirical analysis of 3,150 consumer questionnaires collected in Beijing, Shanghai, Shenyang, Wuhan, Chengdu, and Guangzhou in August 2021, this study established that negative information was more effective than positive information in promoting healthy and sustainable diets among Chinese urban residents. Furthermore, when the information source is a "big V," the impact of information intervention is significant. Overall, low-income groups were more responsive to information interventions and made healthier and more sustainable dietary choices after receiving such interventions.



Group	Content
Control group	Dietary choice experiment
Treatment 1	Positive message (as shown below) + Dietary choice experiment
Treatment 2	Negative message (as shown below) + Dietary choice experiment
Treatment 3	Positive information from China Nutrition Society + Dietary choice experiment
Treatment 4	Negative information from China Nutrition Society + Dietary choice experiment
Treatment 5	Positive information from China Nutrition Society and social media platforms + Dietary choice experiment
Treatment 6	Negative information from China Nutrition Society and social media platforms + Dietary choice experiment
Treatment 7	Positive information from “big V” and social media platform + Dietary choice experiment + Dietary choice experiment
Treatment 8	Negative information from “big V” and social media platform + Dietary choice experiment + Dietary choice experiment

Positive message

1. Increasing the intake of fruits and vegetables can reduce the risk of cardiovascular disease, cancer and tumors (including gastric cancer, lung cancer, esophageal cancer, breast cancer and other diseases).
2. Increasing the intake of milk and its products can increase children's bone density.
3. Increasing fish intake can reduce the risk of all-cause death, stroke, dementia in the elderly or cognitive dysfunction.

Negative message

1. Insufficient intake of fruits and vegetables can increase the risk of cardiovascular disease, cancer and tumors (such as stomach cancer, lung cancer, esophageal cancer, breast cancer and other diseases).
2. Insufficient intake of dairy products may reduce bone density in children.
3. Insufficient fish intake can increase the risk of all-cause death, stroke, dementia in the elderly or cognitive dysfunction.

5.3.2 Behavioral Interventions

The food environment is a critical factor in shaping the food choices of individuals and communities, including the number and location of retail and food service outlets, types of foods offered, and how they are presented and accessed. Behavioral interventions influence consumers' dietary behavior by making adjustments to the food environment, primarily through two channels: changes in the availability and convenience of sustainable and healthy foods.

The availability of sustainable and healthy foods is crucial for shaping consumer choices. Studies have established that workplaces, such as schools or hospitals, that offer more vegetables, fruits, and whole grains and fewer sugar-sweetened beverages and snacks in their cafeterias and restaurants can significantly improve the

quality of consumers' diets and increase their intake of healthy foods (Appleton et al. 2016; Hendren and Logomarsino 2017; Metcalfe et al. 2020). Similarly, an increase in community-based fresh food retailers is associated with an increased intake of fruit and vegetables and a healthier diet among local residents (Morland et al. 2002; Abeykoon et al. 2017). Conversely, an increase in the availability of unhealthy foods in the food environment increases the risk of obesity in the population (Pineda et al. 2021). For instance, studies conducted in China established that an increase in the number of fast-food restaurants around schools or communities increased the risk of obesity among students and community residents (Shen et al. 2019) and that people in communities with more indoor restaurants were more likely to choose to eat out (Tian et al. 2016).

Moreover, consumers' concerns about the



convenience (or accessibility) of food have increased as the economy develops and residents live at a faster pace. Practices such as adjusting product presentation, portion size, and variety and changing default options can influence dietary behavior. For example, making healthier vegetables and fruits the default option rather than high-oil and -salt or ultra-processed foods in school cafeterias can significantly increase students' intake of healthy foods (Hendren and Logomarsino 2017; Metcalfe et al. 2020). Placing vegetables and fruits in locations that are more visible to consumers in retail stores such as supermarkets increases their purchase (Ronto et al. 2022).

According to the "6P" dietary behavior change

framework proposed by WRI (2023), targeting behavioral interventions is critical.⁴ Promoting behavioral changes among individuals responsible for preparing and selling food is an essential part of the intervention. In China, influencers such as chefs, food industry professionals, and food bloggers can help promote the development of new, healthy, and sustainable recipes and meal formats and accelerate their spread to the population. Behavioral change among influential members of a family or social group is also an effective intervention. Mothers' nutritional perceptions significantly affect family meals, and children can become "influencers" of family diets through participation in school nutrition programs (Chen et al. 2022).

Case 5.2 Mama's Kitchen

Mama's Kitchen is a community space focused on promoting low-carbon, healthy, and delicious food choices. It was established based on the Good Food Consensus and Good Food Initiative launched by the Good Food Foundation in 2020. The three main goals of the initiative are to encourage people to adopt plant-based diets, significantly reduce food loss and waste, and improve food production methods.

Mama's Kitchen is leading a revolution in healthy and sustainable food practices through collaborations with chefs, nutritionists, scholars, community residents, farmers, and other sectors. The community-based approach focuses on developing plant-based recipes and ingredients, increasing ingredient biodiversity, educating and training food creators, and encouraging the public to change eating habits toward sustainability and health. By facilitating exchanges between home cooks and professional chefs, Mama's Kitchen uses food to connect people and their families, society, and nature. This promotes a change in lifestyle and dietary behavior, which helps the public understand the concept of healthy and sustainable diets from an everyday perspective.

In 2022, "Bugu Seasons (布谷四季) Mama's Kitchen" coproduced 20 video clips that were released through various platforms such as Chinese TikTok, Kuaishou, and Tencent Penguin. These videos have garnered more than 3 million views, with the highest play count of a single video reaching 1.09 million. Additionally, two seminars were broadcast live on Green Council Media, Baidu, and the Good Food Fund's media platform, with 20,000 online viewers.

5.3.3 Economic Incentives

Market-based economic interventions are effective tools for promoting healthier and more sustainable food choices. These interventions use market mechanisms and economic incentives such as advertising campaigns and price promotions to influence purchasing behavior. They also leverage population segmentation and social media to target specific groups using tailored communication

⁴In the 6P framework for dietary behavior change, the six main target areas for behavior intervention include: the people who prepare food, the product itself, the presentation and description of healthy and sustainable dietary interventions to consumers, promotion of healthy and sustainable foods, placement strategies aimed at increasing consumer likelihood of selecting healthy diets, and policy measures led by governments to encourage dietary change.

strategies. In China, food prices remain a critical factor influencing consumption, particularly for rural and low-income consumers. Research has shown that sustainable and healthy diets tend to be more expensive than conventional diets and that affordability remains a significant barrier for many low-income, minority, and rural communities. For instance, approximately 230 million Chinese people, or one-sixth of the population, cannot afford a healthy diet based on the Chinese Dietary Guidelines. The cost of a nutritious and healthy diet based on these guidelines is approximately RMB11 per person per day, which is higher than the consumption expenditure of many rural low-income groups.

Appropriate price promotions can effectively encourage consumers to choose healthier and



more sustainable diets, although their effects can be mixed. Although discounting strategies increase the consumption of sustainable and healthy foods, they may lead to a higher calorie intake. Further research is required to understand how pricing strategies for different food groups influence consumer choices.

Food policy can also influence food choices through financial incentives such as subsidies. Governments can encourage the production of healthy and sustainable foods by providing subsidies to farmers who grow them as well as making certain types of healthier and more sustainable foods more affordable and accessible to consumers through consumption subsidies. For

example, the U.S. Supplemental Nutrition Assistance Program and Special Supplemental Nutrition Program for Women, Infants and Children have significantly increased the intake of fruits and vegetables among participants with consumption subsidies for these food groups. Conversely, governments can discourage the consumption of unsustainable foods by applying taxes, particularly for those with high greenhouse gas emissions or those that contribute to deforestation. Such taxes can make healthier and more sustainable options attractive to consumers by making them more affordable than unhealthy or unsustainable options.

Case 5.3 Singapore Encourages the Consumption of Whole Grains through Economic Incentives

Singapore's Health Promotion Board (HPB) has successfully increased whole-grain consumption by incentivizing food companies and restaurants to offer more whole-grain options and create a positive food environment for consumers.

HPB partnered with major supermarket chains to promote whole-grain products by offering discounts on brown rice and lowering the prices of other whole-grain foods. Additionally, HPB has worked with noodle suppliers and food vendors to offset costs for companies to develop and market whole-grain noodles at the same price as refined grain noodles.

Given the high frequency of food consumption in Singapore, with more than one-third of the population eating out more than seven times a week and approximately 80 percent eating at food stalls at least once a week, adding whole grains to meals eaten outside the home can have a significant nutritional impact. To encourage stalls to adopt whole-grain foods, HPB provides up to 80 percent of the investment costs, including product and packaging development, marketing, promotion, and trade promotion, through the Healthier Ingredient Development Scheme. Restaurants, cafés, and fast-food outlets are also incentivized to offer whole-grain dishes to diners.

Since its implementation, the program has seen impressive results, with the number of healthy meals sold under the scheme rising from 7.5 million in fiscal year 2014 to 50 million in fiscal year 2017 (HPB 2018). HPB's efforts have created a win-win situation in which consumers can enjoy healthier food options while food companies and restaurants can maintain their profitability by experimenting with different product formulations that strike a balance between health considerations, taste, and manufacturing costs.

5.3.4 Supportive Policies

As concerns regarding climate change and nutrition-associated diseases continue to grow, policymakers and governments worldwide have started to implement supportive policies to promote healthy and sustainable food choices for vulnerable groups such as low- and middle-income individuals, children, and youth. As this transition involves all social aspects of the food system, collaboration across sectors is necessary to introduce supportive policies that encourage a shift in consumer behavior toward healthier and more sustainable choices.

Education departments, health organizations, and other entities can use programs (i.e., nutrition education and nutrition improvement initiatives) to ensure that

vulnerable groups adopt sensitive dietary behaviors. For instance, the Nutrition Improvement Program for Rural Compulsory Education Students in China, which has been implemented since 2011, has significantly improved the nutritional status and physical fitness of rural students. Appropriate meal health education programs in schools can also improve the diet quality of students and increase fruit and vegetable consumption among them (Sassi et al. 2009). Additionally, the environmental impact of nutrition programs cannot be ignored. Stern and colleagues (2022) established that adjustments to school cafeteria diets through the National School Lunch Program in the United States could significantly reduce environmental impacts such as carbon and water footprints.

Considering the positive role of healthy and nutritious dietary intake in reducing disease burden and



improving social welfare, food assistance is a vital policy tool for international organizations and some developed countries to provide essential food sources for low-income and special groups (Brugh et al. 2018; Hidrobo et al. 2014). However, only a few nongovernmental organizations and foundations currently promote food assistance programs in China (e.g., the Oasis Food Bank program), and macro-level policy support is still lacking.

Trade policy is another important tool for promoting sustainable and healthy diets for consumers, requiring attention from relevant departments and corresponding policy adjustments. Trade policies can affect the supply of and demand for sustainable and healthy diets, thereby affecting their prices and consumption. Governments can promote sustainable and healthy diets among

consumers by reducing tariff and nontariff barriers, establishing free-trade agreements, and adjusting import and export quotas. Nevertheless, trade globalization has altered the dietary structure of the local population considerably, increasing the demand for animal-based and processed foods. Studies demonstrate that foreign direct investment has brought Western-style fast food to developing countries, promoting a preference for fried foods and sugar-sweetened beverages among local residents and increasing the risk of overweight and obesity (Tian Xu et al. 2022). Therefore, relevant authorities should improve the direction of foreign trade-related policies, such as foreign direct investment, based on trade liberalization and the transition to healthier and more sustainable goals in the future.

Case 5.4 Nutrition Improvement Program

In recent years, China has made significant strides in improving the nutrition of children and adolescents, with the Nutrition Improvement Program for Rural Compulsory Education Students (NIPRCES) serving as the key component. NIPRCES, a nutrition intervention policy, has significantly improved the nutritional status and overall health of rural students while also promoting educational equity.

NIPRCES was launched in November 2011 with the primary goal of ensuring that all students in rural compulsory education receive a nutritionally balanced diet to improve their health. As of 2020, the project had been gradually extended to 1,762 counties in 29 provinces, including formerly concentrated contiguous counties and local pilot counties, for poverty alleviation and development. According to the Ministry of Education, the pilot nutrition improvement program covered 123,800 compulsory rural education schools nationwide by the end of 2021, benefiting 350 million students. The national standard subsidy has also been gradually increased from 3 yuan per student per day at the beginning of the project to 5 yuan; in 2021, the central financial arrangement for student nutritional meal subsidies reached 26.034 billion yuan.

The focus of NIPRCES includes providing nutritional meal subsidies for students in compulsory education, building and improving student canteens, and offering health-education-related courses. According to data from the Ministry of Health and the Ministry of Education's monitoring of rural students' nutritional health in 2021, the nutritional status and physical fitness of rural students have significantly improved. The average height and weight levels of male and female students of all ages in the monitored areas significantly increased, with a growth retardation rate of 2.3 percent for students age 6 to 15 years, a decrease of 5.7 percent compared to 2012, and an anemia rate of 16.7 percent, a decrease of 4.7 percent since 2012. Additionally, the program positively affected students' nutritional awareness levels. In 2021, 97.6 percent of the 11,776 monitored schools had health-education-related classes or activities, and students' nutritional health awareness was significantly higher than at the beginning of the program in 2012.

Case 5.5 Oasis Food Bank

The Oasis Food Bank, which was established in 2014, is a nonprofit organization affiliated with the Shanghai Oasis Public Welfare Development Center and is the first food bank in China. The organization tackles food waste and inequality in local communities by collecting surplus food, including expired items, from production and distribution sectors. Through partnerships with hundreds of businesses, the Oasis Food Bank collects surplus food and distributes it to low-income individuals, people with disabilities, and other needy families in the community.

The Oasis Food Bank pioneered a local food bank management approach in China, with an operational model that has garnered widespread recognition. The organization collaborates with individuals, supermarkets, food companies, and other businesses to collect surplus food, which is sorted and centrally managed in the food bank's warehouses and distributed based on shelf life. The Oasis Food Bank has established two quality-controlled standards—the Alliance Member Authorization System and the Food Data Management Sys-



tem—to ensure food quality and safety and achieve efficient management.

The organization has made significant strides in reducing food waste and addressing food insecurity while contributing to the goal of a low-carbon diet. As per its 2021 annual report, from 2014 to 2021, the Oasis Food Bank's stores in five cities nationwide had worked with 312 donation partners, collected food worth \$15.51 million, distributed more than 3.5 million meals, and assisted more than 1.25 million people. Furthermore, its efforts reduced food waste by 409 tons and carbon emissions by 7,808 tons.

Currently, the Oasis Food Bank has launched an online food bank, "Oasis Food Co-op" (绿洲盛食社), on Taobao. This online platform realizes a new model of food redistribution that can reach more people, improve the speed and efficiency of food distribution, and serve as a global model.

5.4 Strategies for Implementing Different Types of Interventions

Many studies have examined the efficacy of interventions and techniques for persuading consumers to make healthier food choices. However, few studies have investigated the promotion of both sustainable and healthful food options. To address the health and environmental challenges related to suboptimal diets, producers, processors, packagers, retailers, and governments can get involved in intervention measures such as information provision, enabling the food environment to guide better choices, providing price incentives, and setting restrictions and limitations (Table 5.2). Here, we investigate and assess the efficacy of various interventions based on a review of previous studies.

Table 5.3 summarizes the effects of different types of intervention measures from several review studies that are meant to increase the consumption of plant-based foods and reduce the consumption of meat-based foods.

Interventions designed to provide consumers with information, such as nutrition education and food labeling, can reduce incomplete information, particularly in situations where awareness is low. Previous studies have found mixed results regarding the effects of different types of information interventions, and generalized information tends to have a limited impact. However, interventions that incorporate motivational goals to address specific behavioral barriers can positively promote sustainable and healthy dietary choices (Abrahamse 2020). Regarding interventions aimed at reducing meat consumption, information about health benefits has been found effective (Veul 2018; Kwasny et al. 2021), whereas the role of environmental labeling has been shown to be more limited (Veul 2018). Nonetheless, information about the environmental, health, and animal welfare impacts of diets remains significant (Grundy et al. 2022). Interventions focusing solely on consumer dietary education have had limited effects. For example, a randomized controlled trial in Ethiopia established that child feeding practices and

Table 5.2 Subjects involved in the intervention strategy

Increasing intervention intensities				
	Providing information	Guiding choice	Providing incentives	Restricting options
Market (enterprises)	Provide food labels and claims, such as nutrition labels and carbon labels	Increase the visibility of healthy and sustainable food choices in retail locations	Offer discounts on healthy or sustainable food	Limit the provision of unhealthy or unsustainable food in retail locations
Government	Provide food education to the public about food health and environmental impact	Offer more healthy and sustainable food options (e.g. vegetables and fruits) in public institutions such as schools and hospitals	Tax unhealthy or unsustainable food, subsidize healthy or sustainable food	Restrict the provision of unhealthy and unsustainable food in public institutions

Source: Bailey and Harper (2015); Willett et al. (2019).



Table 5.3 Effectiveness of various type of interventions

Reference	Information intervention	Behavioral interventions	Economic incentives	Intervention objectives
Taufik et al. (2019)	Mixed—text messages are effective while traffic light labels are not	Effective—most effective for increasing consumption of plant-based foods and reducing consumption of animal-based foods	Mixed—economic incentives are effective in promoting greater consumption of vegetables and fruits but ineffective in reducing animal food consumption	Increasing consumption of plant-based foods; reducing consumption of animal-based foods
V e u l (2018)	Mixed—health benefit frames are effective; environmental labels are not	Effective—plant-based default option settings and cutting meat food portions can be effective in reducing meat	Mixed—limited impact, low public acceptance and recognition	Reducing meat consumption
Kwsany et al. (2021)	Effective—health and environmental messages are effective; less evidence on social norms	Effective—effective in reducing meat consumption in specific environments such as restaurants and supermarkets	—	Reducing meat consumption
Hendren and Logomarsino (2017)	—	Effective—effective in increasing fruit/vegetable consumption	Effective—price adjustments are most effective in increasing consumption of vegetables and fruits	Increasing consumption of vegetables or fruits
A b r a h a m s e (2020)	Mixed—providing general information is not effective; providing information in combination with motivational goals to address specific behavioral barriers or information that emphasizes social norms can have a positive impact	—	—	Increasing healthy food consumption
Arno and Thomas (2016)	—	Effective—behavioral interventions can increase healthy food choices by 15.3%	—	Increasing healthy food consumption
Cecchini and Warin (2016)	Effective—food labeling increased healthy food consumption by 18.0%; traffic light labeling was also effective	—	—	Increasing healthy food consumption

Source: Authors' compilation.

Note: — = not applicable .

nutrition improved only when a nutrition education intervention (Behavioral Change Communication) was provided alongside food vouchers (Han et al. 2021).

Behavioral interventions are designed to guide consumers toward healthy and sustainable food choices

by shaping their food environments. Compared with information interventions, studies have established that behavioral interventions, such as adjusting food portions, significantly promote healthy and sustainable food consumption (Arno and Thomas 2016; Taufik et



al. 2019; Kwsany et al. 2021; Cadario and Chandon 2020). Conversely, interventions focused on addressing bounded rationality, such as increasing self-control, have been shown to be effective in promoting plant-based and reducing animal-based food consumption (Abrahamse 2020). Among behavioral intervention strategies, changing food portions has been identified as the most effective (Cadario and Chandon 2020). Ultimately, the choice of the right intervention program should depend on the desired goals and specific context of the intervention.

Behavioral interventions are more effective in reducing unhealthy eating behaviors than in promoting healthy eating behaviors. Previous studies demonstrated that when the intervention strategies aim to increase the consumption of plant-based foods and reduce the consumption of animal-based foods, the environmental-based intervention is the key to increasing effectiveness. However, when the intervention goal includes only one aspect, interventions at individual, social norm, and environmental levels can be effective (Taufik et al. 2019). The effectiveness of interventions also varies in locations, and nudging in food service locations is more effective than that in stores (Cadario and Chandon 2020).

Food-related taxes and subsidies provide effective economic incentives for the transition to sustainable and healthy diets and can help address market failures in sustainable and healthy foods. However, the effectiveness of such policies remains inconclusive and requires further research. Studies suggest that taxes on sin foods (e.g., cigarettes, alcohol, and sugar-sweetened beverages) affect the welfare of low-income consumers more (Allcott et al. 2019b). However, a meta-analysis found insufficient evidence that economic incentives, such as providing economic incentives for the purchase of healthy food or increasing the unit price of meat, can reduce animal product consumption (Grundy et al. 2022).

The adoption of multiple intervention strategies has been found promising in achieving greater sustainable food consumption among consumers (Appleton et al. 2016; Blackford 2021). Offering more nutritious and eco-friendly food options in workplaces and schools and supporting these efforts with interventions such as price reductions, nutritional labeling, and subtle behavioral cues can encourage consumers to consume more fruits and vegetables (Hendren and Logomarsino 2017;

Metcalf et al. 2020). However, it is unclear whether the combination of multiple interventions has a greater impact on consumption than the sum of their individual effects.

5.5 Conclusions and Recommendations

In conclusion, this chapter highlights the importance of multifaceted interventions in promoting a sustainable and healthy dietary transition.

First, although information interventions can be helpful, they need to be carefully designed to address specific behavioral barriers and incentive goals. Second, behavioral interventions that improve convenience and accessibility are more effective, and future policies and intervention strategies could benefit from incorporating behavioral science techniques. Third, economic incentives can have a positive impact on increasing the consumption of plant-based foods but are less effective in reducing meat consumption. Fourth, we emphasize the need for more research on intervention programs for key groups and scenarios to address gaps in our current knowledge. Overall, promoting healthy and sustainable food choices requires a comprehensive strategy that considers all facets of the food system, from consumer preferences to policy interventions.

We propose the following recommendations to promote sustainable and healthy dietary practices:

Food education is paramount in shaping the dietary habits of the population. It should be integrated into early family and school education and expanded to a broader “food education” campaign that imparts knowledge about good dietary practices. Public education interventions using behavioral science, information and communications technology, and targeted interventions for different consumer groups are crucial for raising awareness and literacy levels. This should be encouraged at the institutional, enterprise, social organization, and family levels to achieve multibody participation in “social governance.” Food education should be developed based on both the traditional food culture and changing consumer preferences.

Second, the food industry must collaboratively create sustainable and healthy dietary environments. On the supply side, agriculture and food industry reforms should promote nutrition- and sustainability-



oriented agricultural technology innovation; incorporate sustainability indicators into food production and processing measures; promote diversified, nutritious, and sustainable food; and foster local food nutrition and health industries. On the consumption side, the industry should create a market environment that motivates consumers at all levels of the industry chain to choose sustainable and healthy diets. This can be encouraged by establishing industry regulations, standardized labeling, certifications, and general standards that guide the industry toward nutritional health and sustainability. Additionally, behavioral changes in the food service and retail sectors should be promoted through adjustments in choice architecture, such as changing portions and food presentations, to effectively encourage sustainable and healthy food choices.

Third, to achieve precise nutrition, it is crucial to segment the population, regions, and consumption scenarios to precisely intervene with different groups of people. For population segmentation, it is necessary to provide regional and precise classification guidance for vulnerable populations, including mothers, children, and elderly individuals. Furthermore, promoting nutrition improvement projects in various populations can minimize the burden of diseases caused by nutritional problems. In terms of regional segmentation, policymakers must consider the differences in food culture among various regions to design targeted dietary intervention strategies. Finally, schools, hospitals, community-centralized cafeterias, and other feeding venues can provide the necessary entry points for dietary interventions.

Fourth, a sustainable and healthy food environment is essential for the entire society. Thus, fiscal policies must support the production and consumption of sustainable and healthy foods. Multisectoral cooperation that links various sectors in the food systems and industry chains can incentivize the transformation and upgrading of the food industry chain in a healthy and sustainable direction. Additionally, ensuring that vulnerable and marginalized people can afford sustainable and healthy diets through social security can prevent inequality. Finally, improving relevant laws and regulations can drive society to participate in dietary behavior changes and effectively address nutritional health and sustainability issues.

Finally, future research should focus on the long-

term effects of interventions on dietary behaviors and expand the focus on sustainable and healthy diets. This entails studies that focus on the effects of interventions on actual dietary behaviors and nutritional intake as well as the long-term effects of different types of interventions. Furthermore, future studies should emphasize the consumption of plant-based foods other than fruits and vegetables, such as legumes and whole grains.

References

- Abrahamse, W. (2020). How to Effectively Encourage Sustainable Food Choices: A Mini-Review of Available Evidence. *Frontiers in Psychology*, 11, 589674. <https://doi.org/10.3389/fpsyg.2020.589674>
- Academy of Global Food Economics and Policy (AGFEP), China Agricultural University., China Academy of Rural Development (CARD), Zhejiang University., Center for International Food and Agricultural Economics (CFAE), Nanjing Agricultural University., Institute of Agricultural Economics and Development (IAED), Chinese Academy of Agricultural Sciences., International Food Policy Research Institute (IFPRI). (2022). Reforming agricultural support policy for transforming agrifood systems. http://agfep.cau.edu.cn/art/2022/5/24/art_39031_861011.html
- Afshin, A., Peñalvo, J. L., Del Gobbo, L., et al. (2017). The prospective impact of food pricing on improving dietary consumption: A systematic review and meta-analysis. *PloS One*, 12(3), e0172277. <https://doi.org/10.1371/journal.pone.0172277>
- Allcott, H., Diamond, R., Dubé, J.-P., Handbury, J., Rahkovsky, I., & Schnell, M. (2019). Food Deserts and the Causes of Nutritional Inequality The Quarterly Journal of Economics, 134(4), 1793-1844. <https://doi.org/10.1093/qje/qjz015>
- Allcott, H., Lockwood, B. B., & Taubinsky, D. (2019). Should We Tax Sugar-Sweetened Beverages? An Overview of Theory and Evidence. *Journal of Economic Perspectives*, 33(3), 202-227. <https://doi.org/10.1257/jep.33.3.202>
- Appleton, K. M., Hemingway, A., Saulais, L., Dinnella, C., Monteleone, E., Depezay, L., Morizet, D., Armando Perez-Cueto, F. J., Bevan, A., & Hartwell, H. (2016). Increasing vegetable intakes: Rationale and systematic review of published interventions. *European Journal of Nutrition*, 55(3), 869-896. <https://doi.org/10.1007/s00394-015-1130-8>
- Aschemann-Witzel, J., & Zielke, S. (2017). Can't Buy Me Green? A Review of Consumer Perceptions of and Behavior Toward the Price of Organic Food. *Journal*



- of Consumer Affairs, 51(1), 211-251. <https://doi.org/10.1111/joca.12092>
- Balco, P., & Gracia, A. (2022). Tackling nutritional and health claims to disentangle their effects on consumer food choices and behaviour: A systematic review. *Food Quality and Preference*, 101, 104634. <https://doi.org/10.1016/j.foodqual.2022.104634>
- Blackford, B. (2021). Nudging interventions on sustainable food consumption: a systematic review. *The Journal of Population and Sustainability*, 5(2). <https://doi.org/10.3197/jps.2021.5.2.17>
- Boer, J. de, & Aiking, H. (2019). Strategies towards healthy and sustainable protein consumption: A transition framework at the levels of diets, dishes, and dish ingredients. *Food Quality and Preference*, 73, 171-181. <https://doi.org/10.1016/j.foodqual.2018.11.012>
- Bryant, C [Christopher], & Barnett, J. (2018). Consumer acceptance of cultured meat: A systematic review. *Meat Science*, 143, 8-17. <https://doi.org/10.1016/j.meatsci.2018.04.008>
- Brugh K, Angeles G, Mvula P, et al. (2018). Impacts of the Malawi social cash transfer program on household food and nutrition security[J]. *Food Policy*, 76: 19-32.
- Cabrera, M., Machín, L., Arrúa, A., Antúnez, L., Curutchet, M. R., Giménez, A., & Ares, G. (2017). Nutrition warnings as front-of-pack labels: Influence of design features on healthfulness perception and attentional capture. *Public Health Nutrition*, 20(18), 3360-3371. <https://doi.org/10.1017/S136898001700249X>
- Cadario, R., & Chandon, P. (2020). Which Healthy Eating Nudges Work Best? A Meta-Analysis of Field Experiments. *Marketing Science*, 39(3), 465-486. <https://doi.org/10.1287/mksc.2018.1128>
- Carlsson, Fredrik; Gravert, Christina; Johansson-Stenman, Olof; Kurz, Verena (2021): The Use of Green Nudges as an Environmental Policy Instrument. In *Review of Environmental Economics and Policy* 15 (2), pp. 216-237. DOI: 10.1086/715524.
- Cheng, G., Yang, F., Xiong, F., Zhao, L., Zhang, L., & Wang, Y. (2020). Comparison of nutrition education policies and programs for children in China and other selected developed countries. *Global Health Journal*, 4(3), 72-78. <https://doi.org/10.1016/j.glohj.2020.08.002>
- Chow, C. Y., Riantiningtyas, R. R., Kanstrup, M. B., Papavasileiou, M., Liem, G. D., & Olsen, A. (2020). Can games change children's eating behaviour? A review of gamification and serious games. *Food Quality and Preference*, 80, 103823. <https://doi.org/10.1016/j.foodqual.2019.103823>
- Dogbe W, Gil J M. (2018). Effectiveness of a carbon tax to promote a climate-friendly food consumption. *Food Policy*.
- Engel K, Ruder E H.(2020). Fruit and vegetable incentive programs for supplemental nutrition assistance program (SNAP) participants: a scoping review of program structure. *Nutrients*, 12(6): 1676.
- Friel, S., Barosh, L. J., & Lawrence, M. (2014). Towards healthy and sustainable food consumption: An Australian case study. *Public Health Nutrition*, 17(5), 1156-1166. <https://doi.org/10.1017/S1368980013001523>
- Gao, Z., Li, C., Bai, J., & Fu, J. (2020). Chinese consumer quality perception and preference of sustainable milk. *China Economic Review*, 59, 100939. <https://doi.org/10.1016/j.chieco.2016.05.004>
- Gonçalves, D., Coelho, P., Martinez, L. F., & Monteiro, P. (2021). Nudging Consumers toward Healthier Food Choices: A Field Study on the Effect of Social Norms. *Sustainability*, 13(4), 1660. <https://doi.org/10.3390/su13041660>
- Grundy, E. A., Slattery, P., Saeri, A. K., Watkins, K., Houlden, T., Farr, N., Askin, H., Lee, J., Mintoft-Jones, A., Cyna, S., Dziegielewska, A., Gelber, R., Rowe, A., Mathur, M. B., Timmons, S., Zhao, K., Wilks, M., Peacock, J. R., Harris, J., . . . Zorker, M. (2022). Interventions that influence animal-product consumption: A meta-review. *Future Foods*, 5, 100111. <https://doi.org/10.1016/j.fufo.2021.100111>
- Haghighian Roudsari, A., Veadadhir, A., Amiri, P., Kalantari, N., Omidvar, N., Eini-Zinab, H., & Hani Sadati, S. M. (2017). Psycho-Socio-Cultural Determinants of Food Choice: A Qualitative Study on Adults in Social and Cultural Context of Iran. *Iranian Journal of Psychiatry*, 12(4), 241-250.
- Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology*, 61, 11-25. <https://doi.org/10.1016/j.tifs.2016.12.006>
- Hendren, S., & Logomarsino, J. (2017). Impact of workplace cafeteria interventions on fruit and vegetable consumption in adults. *International Journal of Workplace Health Management*, 10(2), 134-152. <https://doi.org/10.1108/IJWHM-12-2016-0089>
- Herforth, A., Venkat, A., Bai, Y., Costlow, L., Holleman, C. & Masters, W.A. (2022). Methods and options to monitor the cost and affordability of a healthy diet globally. *FAO*. <https://doi.org/10.4060/cc1169en>
- Herman, C. P., Roth, D. A., & Polivy, J. (2003). Effects of the presence of others on food intake: A normative interpretation. *Psychological Bulletin*, 129(6), 873-886. <https://doi.org/10.1037/0033-2909.129.6.873>
- Kelly, B., Vandevijvere, S., Ng, S., Adams, J., Allemandi, L., Bahena-Espina, L., Barquera, S., Boyland, E., Calleja, P., Carmona-Garcés, I. C., Castronuovo, L., Cauchi,



- D., Correa, T., Corvalán, C., Cosenza-Quintana, E. L., Fernández-Escobar, C., González-Zapata, L. I., Halford, J., Jaichuen, N., . . . Swinburn, B. (2019). Global benchmarking of children's exposure to television advertising of unhealthy foods and beverages across 22 countries. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*, 20 Suppl 2(Suppl 2), 116-128. <https://doi.org/10.1111/obr.12840>
- Ko, L. K., Rodriguez, E., Yoon, J., Ravindran, R., & Copeland, W. K. (2016). A Brief Community-Based Nutrition Education Intervention Combined With Food Baskets Can Increase Fruit and Vegetable Consumption Among Low-Income Latinos. *Journal of Nutrition Education and Behavior*, 48(9), 609-617. e1. <https://doi.org/10.1016/j.jneb.2016.06.010>
- Kwasny, T., Dobernig, K., & Riefler, P. (2022). Towards reduced meat consumption: A systematic literature review of intervention effectiveness, 2001-2019. *Appetite*, 168, 105739. <https://doi.org/10.1016/j.appet.2021.105739>
- Larson, N., & Story, M. (2009). A review of environmental influences on food choices. *Annals of Behavioral Medicine : A Publication of the Society of Behavioral Medicine*, 38 Suppl 1, S56-73. <https://doi.org/10.1007/s12160-009-9120-9>
- Liu, R., Hoefkens, C., & Verbeke, W. (2015). Chinese consumers' understanding and use of a food nutrition label and their determinants. *Food Quality and Preference*, 41, 103-111. <https://doi.org/10.1016/j.foodqual.2014.11.007>
- Lohmann, P. M., Gsottbauer, E., Doherty, A., & Kontoleon, A. (2022). Do carbon footprint labels promote climatarian diets? Evidence from a large-scale field experiment. *Journal of Environmental Economics and Management*, 114, 102693. <https://doi.org/10.1016/j.jeem.2022.102693>
- McGeary K A. (2013). The impact of state-level nutrition-education program funding on BMI: evidence from the behavioral risk factor surveillance system. *Social Science & Medicine*, 82: 67-78.
- Metcalf, J. J., Ellison, B., Hamdi, N., Richardson, R., & Prescott, M. P. (2020). A systematic review of school meal nudge interventions to improve youth food behaviors. *The International Journal of Behavioral Nutrition and Physical Activity*, 17(1), 77.
- Ministry of Education of the People's Republic of China. (2022). In the past ten years, the average height of men and women in the areas where China's nutrition improvement plan has been implemented has increased by 4.2cm and 4.1cm. Available at: http://www.moe.gov.cn/fbh/live/2022/54709/mtbd/202208/t20220831_656784.html. 2023-03-23
- Pineda, E., Bascunan, J., & Sassi, F. (2021). Improving the school food environment for the prevention of childhood obesity: What works and what doesn't. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity*, 22(2), e13176. <https://doi.org/10.1111/obr.13176>
- Qi, X., & Ploeger, A. (2021). An integrated framework to explain consumers' purchase intentions toward green food in the Chinese context. *Food Quality and Preference*, 92, 104229. <https://doi.org/10.1016/j.foodqual.2021.104229>
- Rob Bailey, David Ross Harper. (2015). Reviewing Interventions for Healthy and Sustainable Diets. <https://doi.org/10.1787/220087432153>
- Ronto, R., Saberi, G., Leila Robbers, G. M., Godrich, S., Lawrence, M., Somerset, S., Fanzo, J., & Chau, J. Y. (2022). Identifying effective interventions to promote consumption of protein-rich foods from lower ecological footprint sources: A systematic literature review. *PLOS Global Public Health*, 2(3), e0000209. <https://doi.org/10.1371/journal.pgph.0000209>
- Sassi F, Cecchini M, Lauer J, et al. (2009) Improving lifestyles, tackling obesity: the health and economic impact of prevention strategies.
- Sheng, J., Li, H., & An, R. (2019). Effect of dietary environment on dietary behavior and obesity of Chinese residents. *Chinese Journal of Epidemiology*, 40(10), 1296-1303 (In Chinese)
- Sophie, Attwood, Peng Liqing, Zeng Hui, Blondin Stacy, Chen Lei, and Fu Xiaotian. n.d. Opportunities to Achieve Healthy Sustainable Diets in China through Behavioral Science(Upcoming).
- Springmann M, Freund F. (2022). Options for reforming agricultural subsidies from health, climate, and economic perspectives[J]. *Nature Communications*, 13(1): 82.
- Stern A L, Blackstone N T, Economos C D, et al. (2022). Less animal protein and more whole grain in US school lunches could greatly reduce environmental impacts[J]. *Communications Earth & Environment*, 3(1): 138.
- Taufik, D., Verain, M. C., Bouwman, E. P., & Reinders, M. J. (2019). Determinants of real-life behavioural interventions to stimulate more plant-based and less animal-based diets: A systematic review. *Trends in Food Science & Technology*, 93, 281-303. <https://doi.org/10.1016/j.tifs.2019.09.019>
- Tian, X., Zhong, L., Cramon-Taubadel, S. von, Tu, H., & Wang, H. (2016). Restaurants in the Neighborhood, Eating Away from Home and BMI in China. *PloS One*, 11(12), e0167721. <https://doi.org/10.1371/journal.pone.0167721>
- Toft, U., Winkler, L. L., Mikkelsen, B. E., Bloch, P., & Glümer,



- C. (2017). Discounts on fruit and vegetables combined with a space management intervention increased sales in supermarkets. *European Journal of Clinical Nutrition*, 71(4), 476–480. <https://doi.org/10.1038/ejcn.2016.272>
- Toups.K.(2020). Global approaches to promoting whole grain consumption. *Nutrition Reviews*, 78, 54-60.
- van Kleef, E., Vrijhof, M., Polet, I. A., Vingerhoeds, M. H., & Wijk, R. A. de (2014). Nudging children towards whole wheat bread: A field experiment on the influence of fun bread roll shape on breakfast consumption. *BMC Public Health*, 14, 906. <https://doi.org/10.1186/1471-2458-14-906>
- Veul, J. (2018). Interventions to reduce meat consumption in OECD countries: an understanding of differences in succes. <https://theses.uhn.ru.nl/handle/123456789/6391>
- Wang-Chen, Yixi, Nicole J. Kellow, and Tammie S. T. Choi(2022). Exploring the Determinants of Food Choice in Chinese Mainlanders and Chinese Immigrants: A Systematic Review. *Nutrients* 14(2):346.
- Wang, D., Stewart, D., Chang, C., & Shi, Y. (2015). Effect of a school-based nutrition education program on adolescents' nutrition-related knowledge, attitudes and behaviour in rural areas of China. *Environmental Health and Preventive Medicine*, 20(4), 271–278. <https://doi.org/10.1007/s12199-015-0456-4>
- Wang, J., Tao, J., & Chu, M. (2020). Behind the label: Chinese consumers' trust in food certification and the effect of perceived quality on purchase intention. *Food Control*, 108, 106825. <https://doi.org/10.1016/j.foodcont.2019.106825>
- Wang, O., & Scrimgeour, F. (2021). Willingness to adopt a more plant-based diet in China and New Zealand: Applying the theories of planned behaviour, meat attachment and food choice motives. *Food Quality and Preference*, 93, 104294. <https://doi.org/10.1016/j.foodqual.2021.104294>
- Waterlander W E, de Boer M R, Schuit A J, et al. (2013). Price discounts significantly enhance fruit and vegetable purchases when combined with nutrition education: a randomized controlled supermarket trial. *The American journal of clinical nutrition*, 97(4): 886-895.
- Weber, A. (2021). Mobile apps as a sustainable shopping guide: The effect of eco-score rankings on sustainable food choice. *Appetite*, 167, 105616. <https://doi.org/10.1016/j.appet.2021.105616>
- Willett, W., Rockström, J., Loken, B., et al. (2019). Food in the Anthropocene: The EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet* (London, England), 393(10170), 447–492. [https://doi.org/10.1016/S0140-6736\(18\)31788-4](https://doi.org/10.1016/S0140-6736(18)31788-4)
- Woetzel, J. (2019). China's Changing Eating Habits Weigh on Country's Future.Retrieved (<https://www.mckinsey.com/capabilities/sustainability/our-insights/sustainability-blog/chinas-changing-eating-habits-weigh-on-countrys-future>).
- World Health Organization and Singapore Health Promotion Board. Making street food healthier in Singapore: a case study, Singapore. Available at: <http://www.wpro.who.int/noncommunicable diseases/about/>
- WRI. (2023). Opportunities to Achieve Healthy Sustainable Diets in China through Behavioral Science. Working paper.
- Xu, M., & Lin, B. (2022). Towards low-carbon economy by carbon label? Survey evidence from first-tier cities in China. *Environmental Impact Assessment Review*, 97, 106902. <https://doi.org/10.1016/j.eiar.2022.106902>
- Zhang, Y., Li, R., Zhao, Q., & Fan, S. (2023). The impact of peer effect on students' consumption of sugar-sweetened beverages- instrumental variable evidence from north China. *Food Policy*, 115, 102413. <https://doi.org/10.1016/j.foodpol.2023.102413>
- Zhao, R., Geng, Y., Liu, Y., Tao, X., & Xue, B. (2018). Consumers' perception, purchase intention, and willingness to pay for carbon-labeled products: A case study of Chengdu in China. *Journal of Cleaner Production*, 171, 1664–1671. <https://doi.org/10.1016/j.jclepro.2017.10.143>