



CHINA'S FOOD FUTURE

A research programme from
The Economist Intelligence Unit



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Preface

This report is built on a research programme undertaken by The Economist Intelligence Unit (The EIU) between August and October 2020, and commissioned by Metcold. The views and opinions expressed in this publication are those of The EIU and do not necessarily reflect the views of Metcold. The report contains key insights on food supply chain modernisation in China and presents international best practices. The report was produced by a team of researchers, writers, editors and graphic designers, including:

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Executive summary

China's food supply chain is gaining unprecedented attention, from the outbreak of the Covid-19 pandemic, to President Xi Jinping's declaration of "war on food waste"¹ and, most recently, flooding in southern China.² The Chinese government has recognised the issues in the country's food supply chain and made policy commitments to addressing them, notably in the 13th Five-Year Plan (FYP) on Food Safety.³ The private sector is experimenting with emerging technologies for food supply chain modernisation, such as the use of blockchain and Internet of Things (IoT) to enhance food supply chain traceability.⁴ Consumer choice is growing as incomes rise and access to imports expands.

Many challenges remain to ensure China's food security in a safe and sustainable manner. A fragmented supply chain, gaps in regulatory enforcement, and a growing threat from climate change all endanger China's food supply chain in the short and long term. This research programme is the product of an extensive literature review and interviews with industry experts, discussing the process of food supply chain modernisation in China. The research identifies key gaps in China's food supply chain, highlights steps taken by the government, analyses international best practices from Japan, Germany and the United States that can be applied in the China context, and draws implications for food safety, security and sustainability in China's future.

Key findings:

Recent disease outbreaks have exposed food safety issues caused by poor regulatory enforcement. In addition to a lack of regulatory capacity, market fragmentation represents a foundational challenge.

- **The Covid-19 pandemic disrupted food supply chains across the globe, while African swine fever (ASF) devastated China's pork supply.** These massive disruptions exposed the lack of food safety in the Chinese supply chain stemming from inadequate regulatory enforcement. Labour shortages and transport bottlenecks created by the pandemic and the resulting lockdowns interrupted food supply across the globe, illustrating the need for greater resilience. Months earlier, the ASF outbreak resulted in the death of nearly half of China's pigs, or a quarter of the global domestic pig population. These disruptions showed that China's food safety issues could threaten global food security and food supply chains. The Covid-19 pandemic highlighted food safety risks at later stages of the supply chain, specifically wholesale and wet markets. Even though 70-80% of food products pass through these popular traditional markets, Chinese regulators conduct less testing at these markets compared to retail and supermarkets. Unhygienic conditions on pig farms and in transportation, along with the absence of basic disease-prevention measures on farms, allowed the ASF virus to spread throughout China and devastate

pork supply. Poor enforcement of food safety regulations played a role in both highly disruptive disease outbreaks.

- **China's fragmented food system complicates efforts to enforce safety regulations.** Through revisions of its Food Safety Law, China has updated food safety regulations to match international standards. However, as the recent outbreaks show, lack of enforcement has allowed persistent food safety shortcomings across the supply chain. Causes include insufficient enforcement capacity, lack of organisational structure and coherence across agencies, and over-centralisation. The underlying issue to resolve, however, is a market structure that is dominated by vast numbers of small production and processing facilities in the supply chain. Less than 20% of ASF cases originated on large farms, indicating that the minimal food safety arrangements in the small production facilities that comprise much of China's meat supply chain were at the root of the outbreak. Enforcement agencies are unable to ensure uniform compliance with regulations in this environment.
- **Restructuring and enhancing local capacity of China's food safety enforcement agencies will improve food safety, and greater supply chain consolidation may be the only long-term solution.** The 13th FYP acknowledges China's inadequate enforcement capacity – the issue is particularly apparent when considered in the context of China's size and the extent of supply chain fragmentation. A more coherent

organisational structure and empowerment of local enforcement authorities could also improve food safety, but only greater consolidation of food production and processing may be required to solve the underlying issue.

- **Unsustainable food production practices are aggravating China's ecology and could threaten food security.** Food production constitutes 82% of the total emissions from the food industry, and excessive use of fertilisers and pesticides is reducing the fertility of soil and contaminating China's limited water resources. With China's limited arable land, soil degradation is expected to reduce food production capacity by nearly 13-18% and risk China's ability to feed itself.

The experiences of Japan and the United States suggest that the government will have to play a leading role in driving sustainable food production while creating space for other stakeholders to build on their efforts.

- **Sufficient capacity and enforcement tools like product recalls, seizures and injunctions have allowed the US FDA to ensure compliance with regulations.** The Food and Drug Administration (FDA) in the United States makes substantial use of food recalls to ensure high levels of compliance with food safety standards, even as it retains the power to shut down food production and processing facilities through seizure or injunction. Although rarely used, the threat of closure is generally an effective motivator for the food industry to police itself. The structure



of the US food and agriculture industry is more consolidated than that of China, making it easier for regulators to identify food safety hazards and enforce food safety standards.

- Notwithstanding the contrast between largely government-led efforts in Japan and consumer-driven, multi-stakeholder action in the United States, the government has been the driving force behind sustainability efforts in both countries.** The Japanese government is proactively promoting sustainable food production, including organic farming, by providing direct financial support to certified “Eco-Farmers”. While sustainability-conscious consumers in the United States have pushed companies to reduce emissions and source sustainably, lower consumer pressure in Japan has prompted the government to play a leading role. This appears to contrast with the leadership shown by the US agri-food sector in promoting sustainable agricultural practices among suppliers and the role of non-governmental organisations (NGOs) that are educating and training farmers in these practices. However, this broad-based sustainable action has built on years of investment and sustainable agriculture programmes by the US Department of Agriculture. The learning from both countries is that government initiative, especially early on when consumer pressure is insufficient to drive sustainable change, is important for the creation of sustainable supply chains.
- It may fall to the Chinese government to increase public awareness around sustainability and promote scalable sustainable agriculture techniques such as fertiliser management and reduced tillage.** Consumers remain preoccupied with issues of food access due to socioeconomic disparities, and consumer-driven advocacy for sustainable production is limited. The experiences of the United States and Japan show the importance of government leadership in investing in sustainability awareness and conducting sustainable agriculture programmes. By adopting a “farmer-centric” approach and promoting and supporting the adoption of simple practices like fertiliser management and reduced tillage, governments can reduce emissions and environmental degradation. Increasing public awareness through environmental campaigns and certification programmes can precipitate sustainable consumption and prompt private sector action. In the longer run, it may be beneficial for the government to create the space for the food industry to take the lead, along with other actors like environmental NGOs that can educate consumers and farmers.
- Supportive policies and incentives can scale up plant-based meat products from an increasingly popular alternative to a viable food sustainability and security strategy.** Livestock production drives over half of all emissions from the food industry, while ASF has exposed the unsafe conditions of production in

China. These twin concerns of safety and sustainability are driving growing adoption of plant-based substitutes among Chinese consumers. These substitutes could ensure China's future food security with higher protein and land-use efficiency. Government stimulus, through direct investment, incentives and subsidies, could be important to the growth of this nascent industry. The government could also encourage consumption through measures like inclusion of such alternatives in school meal standards, or assigning an economic cost to meat production's negative externalities, as has been proposed in Germany.

Technology applications such as geospatial analysis, automated real-time surveillance, and digital traceability, as well as the development of a cold chain network are emerging to enhance food safety and minimise wastage.

- **China has reduced the impact of locust invasions by utilising technology in a preventive management system based on GPS (Global Positioning System).** The GPS system maps areas with the densest invasions to minimise their migration and prevent crop and pasture damage by deploying extra resources to tackle these swarms as a priority. The success of this system shows that preventive measures can be particularly effective in mitigating the impact of ongoing threats, as locust invasions are not a one-time challenge for China.
- **Food-sharing applications and forecasting models have the potential to address growing food waste concerns in China.** Increasing food waste is a concern not only due to food security reasons, but also given the impact of food waste on global emissions. Digital applications, as seen in Japan, can match restaurants with surplus food with consumers looking for reasonably priced meals. Moreover, forecasting models that combine weather data with sources such as inventory, sales and previous demand, predict expected food demand and can reduce overproduction by manufacturers. At the distribution stage, supply chain analytics and e-tracking can minimise risk of food spoilage. An online system allowing donors and food bank recipients to easily connect, as announced by the Japan government, can also improve the efficiency of the food banks.
- **A surveillance network supported by strong technological infrastructure can enable a quick response to disease outbreaks.** The 2012 norovirus outbreak in Germany was linked to a shipment of strawberries from Shandong province in China. Timely surveillance through an electronic outbreak-reporting system in Germany led to a quick recall and prevented the majority of the contaminated produce from reaching consumers. An electronic system ensures continuous updates and facilitates linkages of apparently independent outbreaks, for example in different states, enabling



subsequent analysis. Similar outbreaks in China can be controlled by increasing monitoring in the supply chain using technology such as chip-based food-traceability systems.

- **Consistent standards governing the cold chain network in China can mitigate increasing food safety incidents due to spoilage.** The cold storage of fresh products minimises risk of food-borne illnesses by reducing the growth of spoilage microorganisms. In China, there are 200 overlapping standards regulating temperature control of agriculture and food products. A majority of these are not mandatory and only serve as recommendations. Many of these also unevenly apply to only certain stages of the food supply chain. The cold chain network can be strengthened by putting in place consistent and coherent industry standards across the food supply chain. Moreover, training and equipping the relevant stakeholders with knowledge of cold chain practices can further strengthen this network.
- **China's capability with emergent technologies presents an opportunity to deploy emerging technologies to increase food production and reduce environmental degradation.** China already has a global leadership position in the interlinked areas of artificial intelligence (AI), robotics, drones and digital technology, indicating significant domestic capacity to deploy next-generation innovations to the food system and overcoming obstacles such as limited land and workforce

shortages. China's digital infrastructure, early adoption of emerging technologies by food industry businesses, and consumer acceptance of digital transactions, can all support the further deployment of technology to modernise the food supply chain.

A photograph of two people, an older man and a younger woman, standing in a greenhouse. They are both wearing brown aprons and smiling. The man is on the left, wearing glasses and a blue and white striped shirt. The woman is on the right, wearing a light blue shirt. They are holding a large basket filled with fresh vegetables, including leafy greens, cucumbers, and carrots. The background shows rows of plants in the greenhouse, with long green cucumbers hanging from a trellis system. The lighting is bright and natural, suggesting an indoor growing environment.

China's food supply chain is gaining unprecedented attention, from the outbreak of the Covid-19 pandemic, to President Xi Jinping's declaration of "war on food waste" and, most recently, flooding in southern China



Section 1: Introduction

China's arable land and water resources are, per capita, far below world averages. The country that is home to one-fifth of the world's population has less than 10% of global arable land.⁵ Its arable land has seen a declining trend in the last decade (Figure 1). Yet China ranks first globally in the production of cereals, cotton, fruit, vegetables, meat, poultry, eggs and fishery products.⁶ This demonstrates a high level of efficiency and productivity, despite resource constraints.

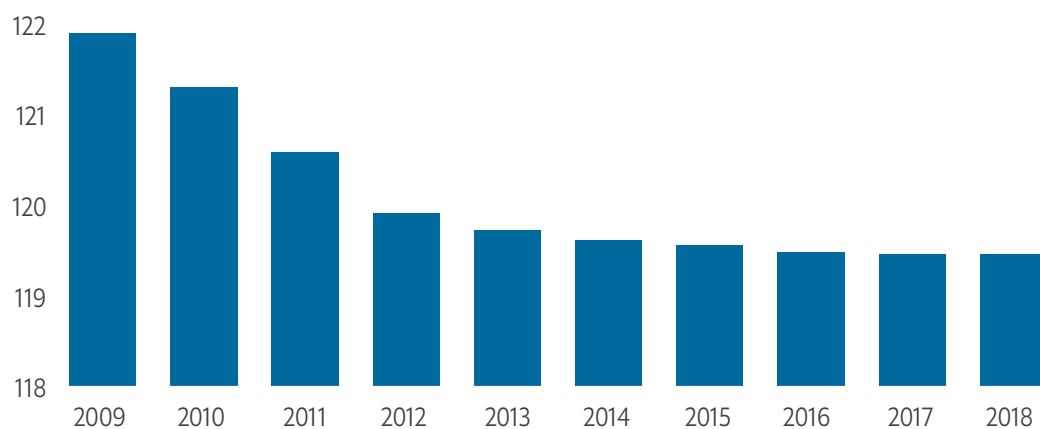
The forces driving modernisation and productivity growth in China's food system include government policies, private sector innovation, and opening up the Chinese food industry to international partners as visible from increasing share of foreign-funded enterprises now investing in the Chinese food processing industry. Technology in particular, from cold chain infrastructure to e-commerce, is improving traceability, efficiency and food

safety.⁷ While general retail sales grew at 10% per year in the 2000s, growth in the supermarket sector was 30%.⁸

Despite these gains, and as the pandemic shows, China's food system is in need of further modernisation. Public concern about food safety and quality is increasing pressure on supply chain participants and the government to strengthen regulatory frameworks and producer monitoring. Consumers' desire for better hygiene, ventilation, and waste management in food retail is one long-term driver of change.

Modernisation has, however, been uneven, with some parts of the food system far more advanced. China's crop production, for instance, is highly fragmented, with an average of 0.6 hectares (ha) assigned to each of the more than 230m rural households.⁹ While this land acts as a social safety net for rural

FIGURE 1: Decline in arable land in China
(Million hectares)



Source: Food and Agriculture Organisation (FAO), United Nations

households, it also hinders the consolidation of farmland into larger plots that utilise modern farming techniques, an issue which government policies are seeking to address.¹⁰ There are also large differences in cleanliness and hygiene between large and small food companies, especially in the meat sector. Last but not least, China must balance the need to increase productivity with eliminating unsustainable practices, from excessive use of chemicals and fertilisers to industrial-scale animal production that, without proper hygiene protocols and surveillance, fosters disease outbreaks.

The forces driving modernisation and productivity growth in China's food system include government policies, private sector innovation, and opening up the Chinese food industry

This report is the product of interviews with policymaking experts, food security and sustainability experts, and food supply chain business leaders. The report highlights the best practices that are driving resilience in China and the three comparison countries (Germany, Japan and the United States). This report:

- Highlights the food policy landscape in China across the three pillars of food sustainability, security and safety;
- Analyses the impact of disruptions such as environmental degradation, the Covid-19 pandemic, ASF and locust invasions to China's agriculture sector;

- Evaluates early responses to mitigate these disruptions and long-term implications for policy response and supply chain resilience;
- Presents a collection of global best practices from Japan, Germany and the United States across the stages of their food supply chain;
- Considers the implications for China's food future, highlighting trends in security, safety and sustainability and steps that China can take to modernise its food supply chain.

This research programme focuses on the three key pillars which lie at the core of a modern food supply chain – food safety, security and sustainability. While the research focuses on each of these pillars individually, our analysis revealed that they are intertwined to a great extent. For instance, although land degradation has been driven by a number of factors such as urbanisation, mining and farming, it is accelerated and exacerbated by climate change. Rising land degradation and desertification along with a doubling of the global population since the 1980s have placed a huge strain on the global food system. Most recent evidence suggests that more than 40% of the world's land has been desertified, making it unsuitable for agriculture.¹¹ In China, climate change driven seasonal drought is expected to impact land and lead to 8% of losses by 2030 in three main crops – rice, wheat and corn – demonstrating a fundamental linkage between food security and sustainability.¹²

The sections that follow present insights into the extent of modernisation in China's food supply chain and implications for the country's food future.

An aerial photograph of a terraced agricultural landscape. The terraces are arranged in a grid-like pattern, with some sections showing rows of young green plants, others showing rows of taller, yellowish-brown plants, and many sections showing bare, reddish-brown soil. The terraces are separated by narrow paths and small channels. In the upper left corner, there are some buildings and a paved area. The overall scene depicts a well-organized and productive agricultural system.

**The food supply chain
accounts for a quarter
of all global emissions,
and 82% of these are
from food production**

Section 2: China's food policy: Towards sustainability, security and safety

China's food sector continues to receive increasing policy attention. In recent years, food security has been one of the topmost priorities of the government. Despite facing significant resource constraints and a highly disaggregated food supply chain, a proactive policy environment has enabled the country to resolve many bottlenecks across the various stages of the food supply chain. This is a result of implementation of multiple policies over the last decade and a timely update of regulations by the Chinese government.

China follows a top-down policy approach with the policies and goals being set at the central level with some flexibility for local governments. In the case of the Five Year Plans (FYPs), for instance, provincial-level plans often differ in some details, but follow the national FYP, which serves as a roadmap.^{13,14} For example, Shanghai and Guangdong published a municipality- or provincial-level 13th FYP for food and drug safety, but both follow the corresponding national FYP. While one of the targets in the national FYP aims to inspect a minimum of four samples per thousand population a year, Shanghai commits to inspect ten samples per thousand population annually, and Guangdong targets five batches.^{15,16}

In the context of these differences that sometimes exist between national and provincial planning, this section highlights the national plans and policy commitments of the Chinese government across the three pillars of food safety, security and sustainability.

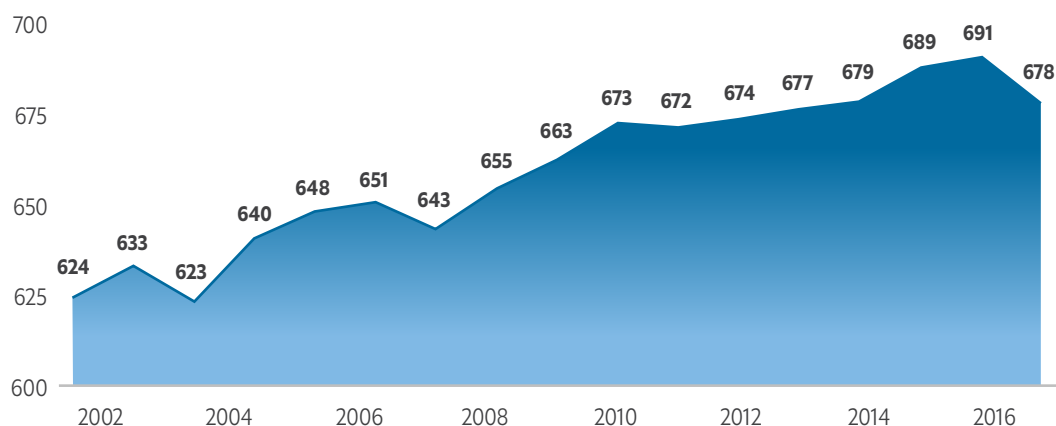
Food sustainability: Cutting emissions, ecological harm and waste

The food supply chain accounts for a quarter of all global emissions, and 82% of these are from food production.¹⁷ In September 2020, President Xi pledged to cut China's emissions to zero by 2060. An important part of achieving this target will be practising sustainable food production, given the impact of food production on emissions.¹⁸ This declaration comes with the backdrop of China being one of the largest carbon emitters in the world. Studies show that China's agricultural activities produce a comparatively higher proportion of carbon. For instance, while greenhouse gases from agricultural production account for 6-7% of total emissions in the United States, in China they account for 16-17%.¹⁹

China has relied heavily on chemical fertilisers and pesticides to boost crop yield, causing significant ecological harm.²⁰ A 2015 government action plan to tackle excessive use has, reportedly, achieved zero growth of both (fertilisers and pesticides) in 2018, three years earlier than planned.²¹ The Sustainable Agriculture Development Plan (2015-30) divides the country's land area into three zones based on their agricultural resources, environmental capacity and ecological type, and links agricultural priorities to each to ensure greater levels of sustainability. Other sustainability policies include the ongoing "Returning Farmland to Forests and Grassland" project,²² which has led to an increase in China's forested area by 33.5m ha,



FIGURE 2: Emissions from agriculture, China
(Megatonnes, 2000-17)



Source: Food and Agriculture Organisation (FAO), United Nations

helping improve agricultural sustainability. A recent ten-year fishing ban on the Yangtze River, scheduled to come into effect before 2021, is another attempt to reduce ecological degradation in the food sector.²³

The growing problem of food waste in China also has repercussions for sustainability in the food supply chain. Globally, food waste accounts for 3.3bn tonnes of CO₂,²⁴ meaning that a quarter of all emissions from food production are for products that never reach a consumer.²⁵ In China, an FAO estimate indicates food lost in the supply chain amounts to approximately 6% of total food production.²⁶ However, the true figure could be higher. A catering industry survey conducted in Beijing, Shanghai, Chengdu and Lhasa estimated that the amount of food wasted was 93 grams per person per meal, or 12% of what is served – not including food

lost at earlier stages of the supply chain.²⁷ One-sixth of the total grain produced in China is reportedly wasted annually in production, processing and transportation because of poor equipment and logistical inefficiencies, and millions of tons of food every year are wasted in the form of leftovers and outdated food thrown away by supermarkets.^{28,29,30}

Following President Xi Jinping's call in the summer of 2020 to "curb waste" in the wake of the coronavirus pandemic and severe flooding,³¹ China launched the "Clean Plates 2.0" campaign to encourage the public to stop wasting food.^{32,33} Although the details of the campaign are not exactly known, it has created a trigger to reduce food wastage at the organisation level. Initial steps include an "N-1" rule which implies that a group of diners may order a limited number of dishes, and a requirement for schools to

encourage students to share pictures of their post-meal empty dinner plate. Previously, the Chinese government supported a grassroots campaign of a similar nature that began in 2013, "Operation Empty Plate", focusing on the banquet feasts often held by government officials.³⁴

Food security: Balancing import risk with domestic production constraints

Food security has long been a priority for policymakers as China's arable land and water resources per capita are below the world average.³⁵ Grain self-sufficiency, in particular, has been a persistent concern, identified by the State Council as "The Grain Issue".

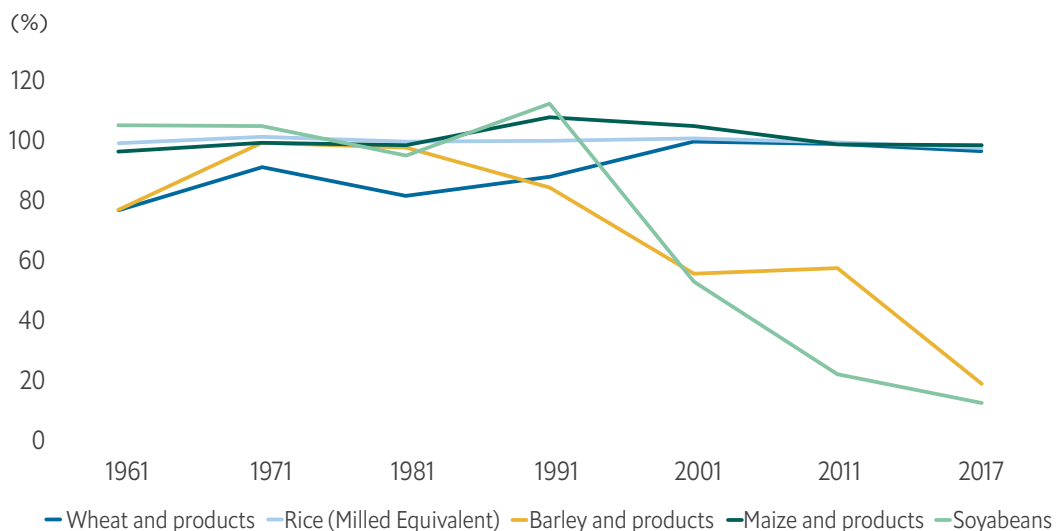
Starting in 1996, the government set a grain self-sufficiency target of 95% under "normal conditions".³⁶ Self-sufficiency ratios of rice and

wheat have surpassed this figure, whereas soybean sufficiency has dramatically fallen (see Figure 3). Some commentators suggest that the fall in soybean self-sufficiency might reflect a strategic decision to import the land-intensive crop instead of growing it on China's own limited arable land,^{38,39} with recent research indicating a trade-off between food security and soybean production.⁴⁰

One-sixth of the total grain produced in China is reportedly wasted annually in production

Noting the trade-offs between import reliance and domestic production constraints, China redefined its food security strategy in 2013 to opt for

FIGURE 3: China's self-sufficiency ratios of grains, 1980-2017³⁷



Source: Food and Agriculture Organisation (FAO), United Nations



“domestic supply with moderate imports”. Including imports in the policy approach shows the need to meet growing demand for food items such as meat, animal feed and edible oil.⁴¹ In 2019, the State Council published a food security white paper outlining the government’s priorities for enhancing food system productivity.⁴² By 2020, the plan aimed to achieve 124m ha of cultivated land, of which 53.3m ha will be high-quality farmland, increasing to 66.7m ha of high-quality farmland by 2022. In addition, the white paper states an intention to implement major hydro construction projects for water conservation and supply, improve farmland hydro facilities, and increase water resource utilisation efficiency. The paper acknowledges that, despite recent successes in securing a stable grain supply, China will continue to face challenges in achieving a sustainable increase in output.

In 2019, the State Council published a food security white paper outlining the government’s priorities for enhancing food system productivity

Food safety: Better monitoring and changing consumer patterns

China’s food policy framework has been influenced by a series of food safety scandals in the past two decades that attracted increased public and government scrutiny of food safety legislation.⁴³ While official records show less

than 20,000 major food poisoning incidents per year in the first decade of this century, the true number is likely to be much higher due to widespread under-reporting.⁴⁴

A large share of the food safety incidents have occurred in production and processing. A paper that examined food safety incidents in Beijing between 2004 and 2013 found that 73% of the 295 incidents occurred at these two stages.⁴⁵ More recent national level research puts the number at 67% in 2016 and 45% in 2017.⁴⁶ In particular, man-made chemical hazards were responsible for about a quarter of acute foodborne illness incidents in China between 1999 and 2010.⁴⁷ Hazardous chemicals find their way into food production and processing through multiple channels, including land and water pollution, agrochemicals abuse and the illegal use of food additives. For example, factories built next to farmland threaten to contaminate fields with industrial waste.⁴⁸ In 2008, researchers from Nanjing Agricultural University found that 10% of 91 rice samples randomly collected from Chinese markets contained standard-exceeding levels of cadmium, an extremely toxic heavy metal element.⁴⁹

Excessive use of fertilisers and pesticides in production also poses a food safety threat at the consumption stage. Improper application and overuse of pesticides on agricultural products can leave a high amount of residue on produce that consumers are eating. China is the largest producer and user of pesticides. Until 2009, 30% of the pesticide market in China consisted of acutely toxic and illegal pesticides. With stricter legislation in 2009, regulation of pesticides came under the purview of the

Ministry of Agriculture, which specifies residue limits for pesticides and publishes it along with the Ministry of Health.⁵⁰ Most recently, China updated the maximum residue limits (maximum amount of pesticide residue on food products) for more than 7000 items,⁵¹ however the number of pesticides and food products being regulated in China is still much lesser than Europe, Japan and the United States.⁵²

Meanwhile, a large number of food safety incidents are linked to illegal food additives. Studies found that food additives were responsible for 43% of food safety incidents in Beijing between 2004 and 2013,⁵³ and 12% of deaths caused by acute foodborne illness nationwide between 1999 and 2010.⁵⁴ In fact, food additives are behind a number of the most notorious incidents, including the 2008 melamine milk incident, where producers added melamine (a chemical compound used in making plastics) to dairy products to make them appear high-protein,⁵⁵ causing urinary tract stones in over 290,000 babies.⁵⁶

One year after the melamine milk incident, the government passed the Food Safety Law, which covers the production, processing, transportation, distribution and storage of food products.⁵⁷ It is one of the two main components of legislation that make up the legal framework governing food safety. The other piece is the Agricultural Product Quality Safety Law, which governs the production of primary agricultural products.⁵⁸ Both of these laws cover other areas such as the production and sale of food additives, food disinfectants, and the packaging and labelling of agricultural products. By stipulating minimum traceability requirements, these laws have promoted innovation such as

adoption of cutting-edge blockchain-driven traceability platforms.⁵⁹ Improved regulatory efforts have also contributed to a decrease in the frequency of food safety incidents. In 2017, the number of food safety incidents covered online by mainstream sources averaged to 54 incidents per day, 52% down from the 2008 to 2017 average.⁶⁰

While controlling pollution and chemical abuse at the production stage remains a top priority in China, industry experts expect Chinese consumers to demand better traceability and higher levels of food safety in the entire food supply chain in the future, a result of rising living standards and changing consumption patterns.⁶¹ For instance, Chinese consumers' appetite for processed and frozen food products is growing rapidly, particularly in the wake of the Covid-19 pandemic.⁶² However, most of China's agricultural products do not enter the cold chain yet, posing threats to food safety. Only 22% of fruits and vegetables, 34% of meat, and 41% of aquatic products entered the cold chain in 2015,⁶³ compared to rates of 95-100% observed in Europe.⁶⁴ Recent policy documents have tried to address this issue. In 2017, the government published a policy document on cold chain logistics,⁶⁵ emphasising the importance of developing a comprehensive cold chain that provides temperature control for products throughout the supply chain from "farm to fork". It also covers the need for up-to-date infrastructure, sectoral standards and effective regulation.



The 13th Five-Year Plan for Food Safety



The 13th FYP for Food Safety, covering the period 2015 to 2020, identifies multiple challenges including food contamination and fraud, inadequate national food safety standards, insufficient regulatory enforcement capacity, and fragmentation of the food production system. It covers targets for production, processing, distribution and consumption, including expansion of green pest control methods for 30% of key crops,⁶⁶ and the expansion of mechanical fertilisation for 40% of the key crops area, and expansion of organic agriculture to 3m ha. It also sets out nationwide early warning systems for food-borne diseases and targets to expand national food safety inspections, including monitoring throughout the supply chain in infant milk powder, fresh agricultural products and alcoholic food traceability.

The plan emphasises research and development (R&D), in which China is rapidly becoming a world leader,⁶⁷ prioritising technologies for the rapid detection of biological and chemical food safety hazards. It identifies the cold chain as an area in need of priority development, especially high-efficiency, environmentally friendly cold chain equipment and green logistics optimisation technology.

Objectives

Example targets



Enhance food safety sample inspection to cover all types of food

Test a minimum of four food samples per thousand population each year, of which at least two should be tested primarily for pesticide and animal drug residues.



Achieve effective control of pollution at the source of agricultural production

Cover a minimum of 30% of key crops⁶⁸ with green pest control methods. Methods include planting disease- and pest-resistant crop varieties, using pheromone traps, and deploying environmentally friendly pesticides that are highly efficient, less toxic and low-residue.⁶⁹



Reinforce on-site food safety inspections comprehensively

Inspect all food producers and sellers at least once a year and standardise enforcement procedures.



Establish more comprehensive food safety standards

Develop new standards and revise existing ones for all daily consumption food items, and revise existing food safety standards.



Enhance regulatory and enforcement capacity; improve technological support

Enhance food safety testing capacity at all levels and match international standards in the testing of imported and exported food.



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Simultaneous human health, animal health, and ecological shocks are putting pressure on China's food supply chain

Section 3: Food supply chain disruption

China's food system is closely entwined with the dynamic and unpredictable processes of climate change and ecological degradation, and shock events emerging at the intersection of humans, food systems and the environment—notably, outbreaks of diseases affecting livestock and sometimes humans. This section examines key disruptions—African swine fever (ASF), Covid-19, and a locust invasion—and assesses the response of both government and the private sector.

Simultaneous human health, animal health, and ecological shocks are putting pressure on China's food supply chain

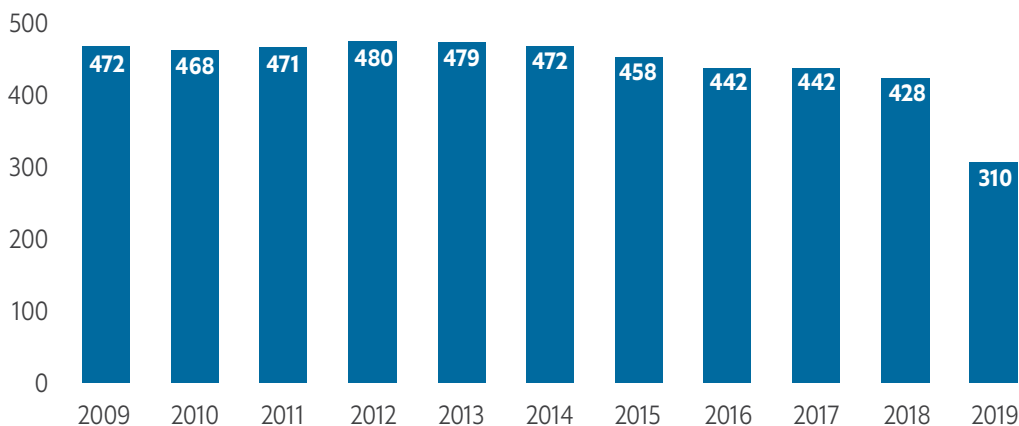
The Covid-19 pandemic has upended global food supply chains and exposed a lack of resilience and flexibility. The crisis has revealed a lack of food safety testing in parts of the supply chain. One study found that food safety test data is heavily skewed towards retail and supermarkets,

with under-sampling of wholesale and wet markets. Regulators reportedly allocate half of tests to formal retail, even though between 70% to 80% of food products pass through wholesale markets or wet markets.^{70,71} The pandemic has also caused logistical challenges in China's food system, including shortages in seasonal labour to pick fruit and vegetables, and disruptions to processing due to facilities shutdowns.⁷² Transport bottlenecks have hindered the movement of food, in particular the decline in air passenger travel and its concurrent decline in air cargo capacity.⁷³

African swine fever is a severe viral disease affecting domestic and wild pigs. While historically reported in East Africa and parts of Europe, South America and the Caribbean, over the last 15 years it has been reported in multiple additional countries, including in Asia.⁷⁴ ASF has taken a heavy toll in China, leading to the deaths or culling of around half of China's estimated 440m pigs.^{75,76}

FIGURE 4: China's hog population

(Millions)



Source: National Bureau of Statistics



Globally, one-quarter of the world's domestic pigs have died this year from ASF. High-density, large industrial pig farms are breeding grounds for the disease, but smaller farms, with lower compliance with safety and food hygiene standards, are also at risk.⁷⁷ As well as the contagion process, outbreaks are in part connected with extreme weather events. Heavy flooding in southern China is thought to be one cause of the disease's spread. A survey of small pig farmers, corporate farmers, traders and slaughterhouses in 20 provinces revealed that dozens of ASF cases surfaced after heavy rains in southern China and, because infected pigs are often buried, rising groundwater facilitates the spread of the lethal disease.⁷⁸

Pest invasions are a major economic threat to Chinese agriculture, and their frequency could increase due to the link with climate change. To deal with locusts, an estimated 1.5m ha of land are treated annually, with 127 field stations and 2,000 technicians involved in monitoring and control.⁷⁹ Other species of pest could bring more severe outcomes. Fall armyworm took only four years to spread

across the whole of Africa after first detection, devastating the continent's farms in the process.⁸⁰ In Kenya alone it wiped out one-fifth of the maize crop in 2019.⁸¹ First detected in China in January 2019,⁸² the fall armyworm had spread to 1.13m ha of land by the end of that year.⁸³ By August 2020 it had spread to the north-eastern corn belt in Liaoning,⁸⁴ and is now a major threat to corn production.⁸⁵ There is concern that many crop pests and pathogens are already present and unreported,⁸⁶ and that climate change will increase the likelihood of invasions by new pests by creating more favourable conditions.⁸⁷

Early responses to disruptive threats include technology, policy and R&D

Responses to all three disruptive events span both short- and long-term measures. In the short term, government intervention has been quick and effective in some respects. There has been a swift deployment of technology in response to all three threats. GPS systems helped monitor



coordinates of locusts, with data shared via analytics platforms informing bulletins on likely infestation areas and digital mapping, enabling the deployment of extra resources to tackle areas with the densest swarms as a priority.⁸⁸ R&D measures to develop vaccines for disruptive disease outbreaks are a second category of early-response interventions. In August 2020, the Ministry of Agriculture and Rural Affairs announced the expansion of ASF vaccine trials led by the Chinese Academy of Agricultural Sciences from 3,000 to 10,000 hogs.⁸⁹ According to the Ministry's statement, considerable progress has been made towards a deployable vaccine, with no virus transmission detected among vaccinated pigs, sows in oestrus (a period of fertility) and breeding normally, and no miscarriages reported, and with vaccinated pregnant sows delivered normally.

Policy measures to contain Covid-19 have also been effective. China's lockdown of Wuhan appears to have limited the spread of the virus across the country's wider geography. Within the food sector specifically, the government took measures to address the negative impacts. Local governments, for instance, promoted the adoption of a "shared labour model" to mitigate labour shortages as employees unable to work in sectors such as catering temporarily joined e-commerce companies in the food delivery sector. Such employee-sharing schemes softened the blow to pandemic-hit businesses and allowed delivery companies to meet increased demands.⁹⁰ At the food production stage,

local governments advised farmers to employ returning migrant workers to assist in harvesting,⁹¹ while in some areas of Hubei, a colour-coding system was used to identify virus risk in the production sector. This allowed farming activities in green zones to continue, with temperature checking, sanitation and self-protection measures in place. In yellow zones, farming is monitored, with individuals working at safe distances, while farming is prohibited in red zones.⁹²

China's technology sector has also been an essential ally in short-term food system response measures, especially in the Covid-19 response. As restaurants and businesses were disrupted by the pandemic, food supply companies turned to digital platforms to serve customers, offering online deliveries to meet consumer demand during the pandemic. Liu Yu, Chief Operating Officer at Xinliangji Food, a food supply chain company in China, claims that Xinliangji saw a reduction in customers as restaurants closed down but was able to rejuvenate the business via digital channels, like Tmall, a business-to-consumer e-commerce platform and community group-buying, to directly serve consumers.

Long-term resilience requires strategic plans, sector consolidation and consumer behaviour changes

Short-term responses to food system shocks are not sufficient. Measures are also needed to address underlying factors that create such risks in the first place. To further

enhance food safety, the government is moving to restructure meat production, so as to replace small farms where compliance with safety and hygiene standards is lower, with modern, large-scale industrial production.⁹³ The government is also clamping down on the farming and commercial trade of wild animals. Prior to the pandemic, around 50 protected species could be farmed, with others, like snakes, bred and sold for food, as pets, or for medicinal use.⁹⁴ Markets that bring together multiple wild animals in close contact in unhygienic conditions significantly increase the risk of disease transmission between species and, ultimately, to humans. The government has moved to ban segments of this trade, such as snakes,

and temporarily shut down marketplaces where further signs of coronavirus have been found, such as the Xinfadi market in Beijing which was shut three times in June 2020.⁹⁵ Key institutions monitoring and restricting illegal wildlife trade include the National Forestry and Grassland Administration. A growing number of volunteers informing the agency of illegal activity are significantly aiding that effort.⁹⁶ Another measure deployed to eliminate the trade of species that may be vectors of zoonotic disease is upgrading their protected status. Several research studies have suggested that pangolins may have transmitted Covid-19 from bats to humans, and while this research is inconclusive, the pandemic has

Ecological degradation: A slow-burn crisis



While short-term food shocks require attention and policy response, China's food system also faces a longer-term disruptive threat in the form of environmental stress and the impact this will have on production. The country has become the world's largest user of fertiliser and pesticides.⁹⁷ Chinese farmers apply more than three to four times the amount of chemical fertilisers and pesticides per hectare than farmers in the EU or the United States.^{98,99} Yields are declining, and land is increasingly rendered unusable. Fertilisers are usually nitrogen-based and therefore cause soil acidification, reducing the fertility of the land until it is unsuitable for cultivation. Forecasts suggest that cropland area may

even decline to 110m ha by 2030, reducing the food production capacity by 13-18%, and prompting a food security crisis.¹⁰⁰

China accounts for less than 6% of global water resources, and water pollution threatens the already scarce supplies.¹⁰¹ Causes include fertiliser use, overfishing, industrial pollution and food/agricultural waste.¹⁰² China has committed to ensure the safety of agricultural water and restore aquatic ecosystems. It is constructing 150 major water conservancy projects, which require an investment of RMB1.29trn (US\$184.38bn).¹⁰³ It has also announced a ten-year ban on fishing on the Yangtze River to help replenish depleted freshwater fish stocks.

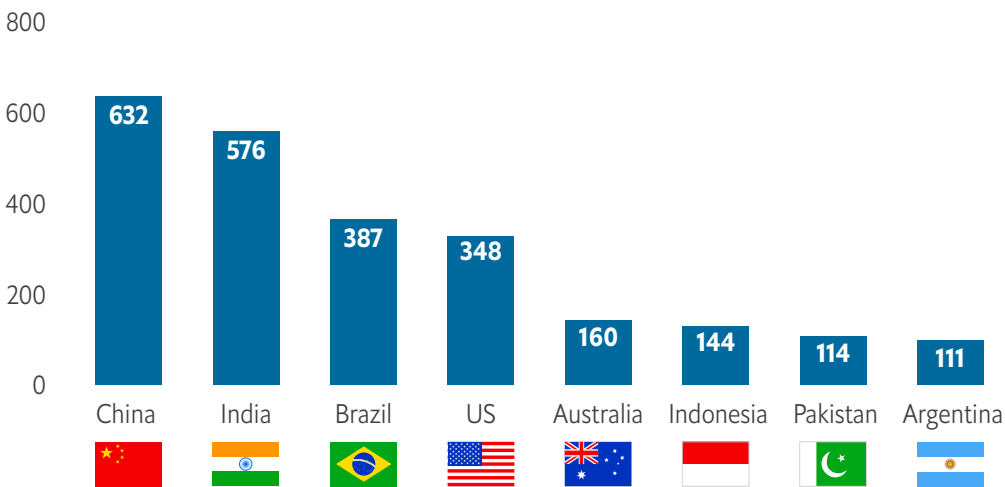


underscored the need to stop the trade of high-risk animals.¹⁰⁴ Pangolins are also an endangered species, and China upgraded their protection status in June to enhance monitoring and protection measures.¹⁰⁵

Technology and R&D such as the use of biotechnology and genetically modified pest-resistant corn in integrated pest-management programmes can enable long-term food modernisation.¹⁰⁶ Agricultural science is a critical mechanism for increasing sector productivity without reliance on ecologically damaging fertiliser and chemical use, which is excessively deployed in China (see box before).¹⁰⁷ The country is progressing towards reduced use of harmful chemicals through innovations including agricultural technology, crop rotation, and recycling of livestock excrement.¹⁰⁸

Food sector businesses are increasing their utilisation of cold chains, a critical contributor to food modernisation. In a recent survey of Chinese consumers, 43% of respondents claimed to have increased their purchase volume of frozen products. Of that group, 57% had switched to frozen and chilled products for stocking up as a result of disrupted supply chains.¹⁰⁹ Expert interviewees also noted that companies are exploring ways to increase the deployment of automation as a response to the challenges of limited mobility and social distancing during the pandemic, and raising their overall food safety standards. Pandemic-induced concerns around hygiene, cleanliness and disease control will all increase in the coming months and years. Other measures to improve overall food sector sustainability include major investments in water conservation¹¹⁰ and bans on fishing in certain depleted waters.¹¹¹

FIGURE 5: Top CO₂eq emitters in agriculture
(Average, 1990-2017, megatonnes)



Source: Food and Agriculture Organisation (FAO)

A photograph of a farm at sunrise. In the foreground, a large flock of brown chickens is scattered across a grassy field. Two people are visible: one in the middle ground carrying two blue buckets, and another in the foreground on the right wearing a hat and carrying a blue bucket. The sun is low on the horizon, creating a warm, golden glow. A fence and trees are visible in the background.

China's food modernisation challenges are not unique. Climate change and environmental stress are affecting food systems across the world



Section 4: Global best practices in the food supply chain

China's food modernisation challenges are not unique. Climate change and environmental stress are affecting food systems across the world. Food safety and traceability are priorities for all consumers, regardless of location. What best practices and strategies are emerging in lead countries across contexts?

This section draws together ideas, trends and best practices from three countries, selected on account of their high performance in The EIU's Global Food Security Index, a benchmarking assessment informed by 28 indicators and applied to 113 countries. Japan, the United States and Germany have been selected due to their strong performance across multiple public and private sector domains including technology adoption, policy, and collaboration models.

Japan: Deploying emerging technologies to address labour shortages, promote sustainability and reduce food waste

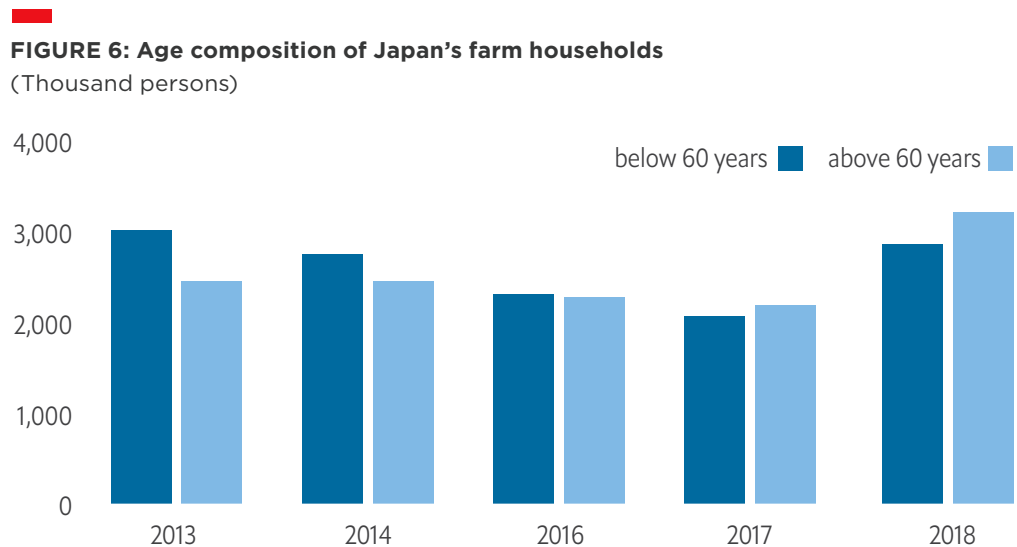
Japan's food supply chain faces many challenges, chiefly its limited arable land and an ageing agricultural workforce – a reflection of the country's wider demographic struggle as well as the limited interest of younger people in working in the agriculture sector. Its heavy reliance on food imports results in Japan having among the lowest food self-sufficiency ratings in the world, with only 37% (2018) of calories consumed being produced locally.¹¹² Yet these pressures have also encouraged significant innovations, from automation and smart farming to codifying farmer

expertise in pig breeding to apps that reduce food loss and waste.¹¹³

Tech-enabled sustainable production

Despite its demographic and resource constraints, Japan's agriculture sector actors, including farmers, agricultural companies, research institutes and public sector agencies, are successfully utilising both technology and policy innovation to increase food production and cut waste and loss. Smart farming has been one leading approach. The IoT and AI tools are increasing the efficiency of fertiliser and water use, such as the deployment of soil and light sensors from which data is analysed by AI systems, thus minimising inputs to the amount required. Techniques like "Fertigation"—which uses narrow pipes to place water and fertiliser at the roots of growing crops—help to reduce input requirements.¹¹⁴ Drones and unmanned agricultural robots are other tools that can optimise input usage and increase productivity in spite of labour shortages and resource constraints.^{115,116}

Japanese food companies are using data analytics to improve livestock sector productivity and safety. NH Foods' Smart Pig Farming initiative, for instance, uses AI to spot the many signs of sow breeding readiness, like changes in appetite and behaviour. Such expertise is typically acquired by human workers over many years, which poses a problem given Japan's ageing food sector workforce. This system, combining cameras, environmental sensors and analytics, helps automate decision-making and improve health monitoring in general.^{117,118}

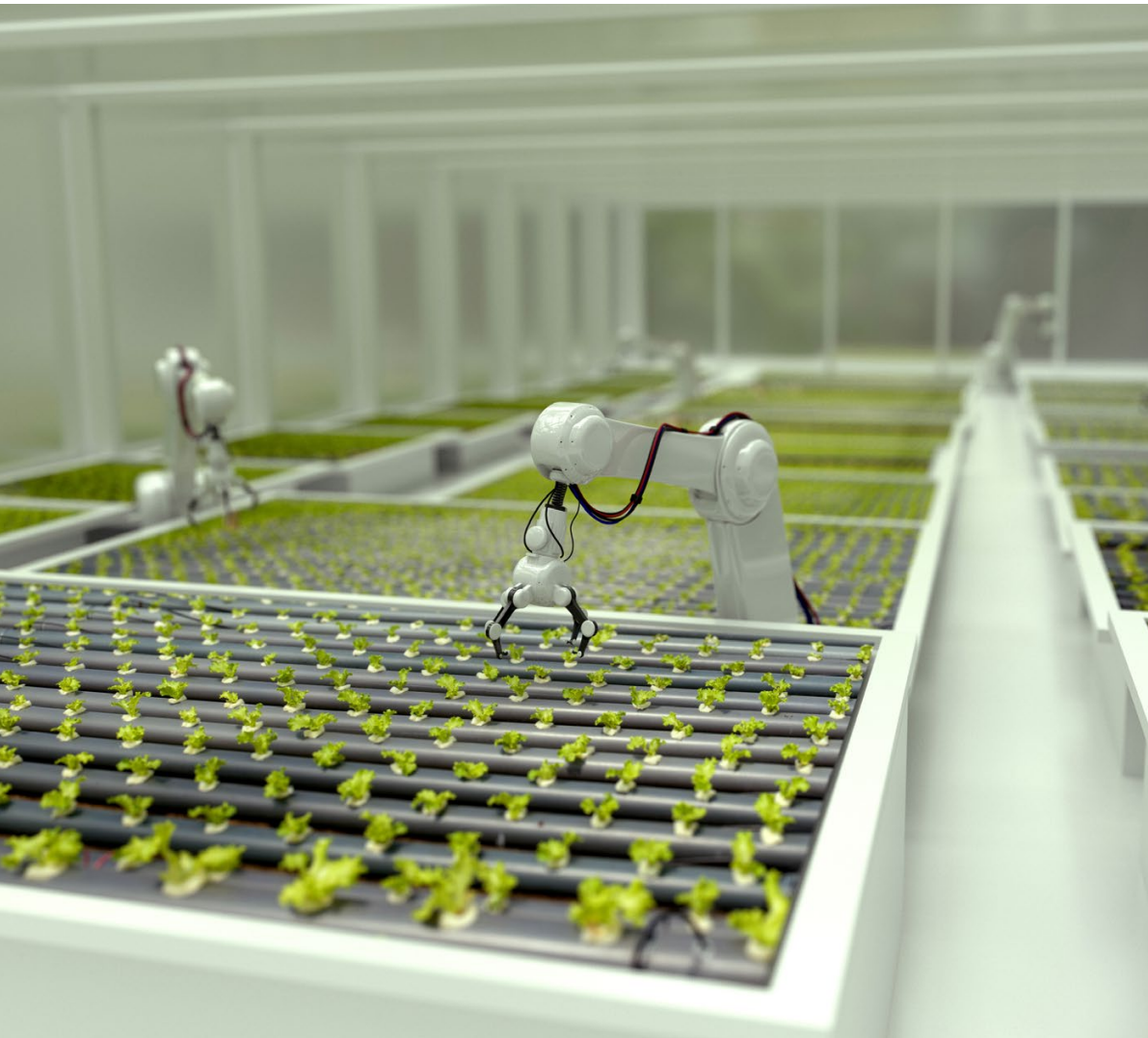


Source: Ministry of Agriculture, Forestry and Fisheries (Japan)¹¹⁹
Note: The source does not report data for 2015.

Japanese companies are also harnessing biotech innovations to improve resilience and sustainability. The amount of agricultural land needed to grow livestock feed ingredients is one challenge.¹²⁰ DSM Japan, a chemicals company with significant interests in the nutrition space, has developed additives for livestock and poultry feed that make food production more sustainable. Feed enzymes improve digestibility and substantially reduce the amount of feed and land needed to meet the growing demand for animal protein. Other interventions include vitamin E feed additives that increase meat shelf life; activated forms of vitamin D poultry feed additive that increase eggshell strength, resulting in less breakage in transport and thus lowering food waste; and an enzyme

additive to livestock feed that allows animals to digest phosphorus, preventing the emissions and soil pollution that result from undigested phosphorus.

Along with reducing the environmental toll of animal protein production, DSM Japan has developed alternative plant-based protein sources, including from canola, for people with soy intolerance. The company has incorporated sustainability into its ethos, in part as a response to changing consumer attitudes, according to Kazunori Maruyama, DSM Japan's president. "The world is changing. Ten years ago, the general belief was that, as a company, you either focused on profit or improving the world, but that you couldn't do both. In the future, if companies are not treating the earth well, the company cannot



be recognised as a good company and people won't work for or buy from that company."

The government has also played a role in steering the overall sustainability agenda. Government innovation programmes are increasing stakeholder awareness

and stimulating technology adoption and deployment. Examples include efforts by the Ministry of Agriculture, Forestry and Fisheries and central government-coordinated innovation programmes. The government encourages sustainability through national strategies. The Ministry

of Agriculture, Forestry and Fisheries has implemented measures linked to the UN Sustainable Development Goals, including direct payments for environmentally friendly agriculture and a scheme promoting Good Agricultural Practices (GAP), with actions to promote food safety, environmental conservation and worker safety. As of 2018, there were 631 certified GAP farmers in Japan.^{121,122} By creating this framework for sustainable agricultural practices, the government is spearheading the adoption of sustainability in production and creating opportunities for consumers to make informed choices. It is ultimately the consumer who pays a premium for a “sustainably produced product” and rewards the producer for following these practices.

Smart matching to slash food waste

Japan offers successful examples of the use of technology at the other end of the supply chain in order to reduce food waste. An estimated 70% of food loss in Japan originates from the business sector rather than at the household level, including manufacturers, wholesalers, retailers and restaurants.¹²³ Institutional food loss is primarily attributed to the “one-third rule”, which requires food producers to deliver products within the first third of the period between the production and expiration dates. If delivery is not met within this deadline, retailers have the right to refuse products from wholesalers.¹²⁴

To address this wastage problem, the Japanese Meteorological Association has partnered with a technology company¹²⁵ to create a food demand forecasting model which combines

weather data with other sources such as inventory, sales, and previous demand, to generate forecasts of food demand, allowing manufacturers to produce optimal quantities of packaged food products, rather than overproducing. Food-sharing apps are playing a role too. Platforms like Reduce Go, Tabete, and Food Passport¹²⁶ match restaurants wishing to offload surplus food with consumers looking for reasonably priced meals.

Innovators are finding ways to re-use waste. The Okaeri Yasai Project, initiated in 2008 in Nagoya, collects surplus food from supermarkets, restaurants, and school canteens, and turns it into compost to grow vegetables. In 2019, the initiative was awarded the Biodiversity Action Award by the Japan Committee for the United Nations Decade on Biodiversity.¹²⁷ In 2020, the government announced plans to improve the efficiency of Japan's food banks through an online system allowing donors and recipients to easily connect.¹²⁸ Companies are also promoting sustainability by sharing distribution networks. Kewpie Corp. cooperates with non-food manufacturing companies like Lion Corporation and Japan Pallet Rental Corporation by sharing distribution networks and channels, reducing distances travelled by 80%, all while saving costs.¹²⁹ The government has also adopted targets to utilise leftover agricultural biomass, such as rice straw and livestock waste. In 2010, it adopted “The National Plan for the Promotion of Biomass Utilisation”, which sets quantitative targets for the conversion of biomass into, for example, bioplastics, biofuels, and power generation.¹³⁰



The United States: Enabling regulatory steps and private initiatives are driving sustainability and higher safety standards

The US agriculture sector is among the most productive in the world and is a major export sector for the national economy. America exported US\$136.7bn worth of agricultural products in 2019.¹³¹ The country is at the forefront of agricultural and biotechnology innovation in both the private sector and academic institutions, and has a long history of government funding for agricultural science R&D.

Private sector innovation turns to sustainability

One current trend of relevance to China is the increasing utilisation of scientific sustainability practices. Fertiliser management, intercropping, intelligent crop rotation, livestock integration and

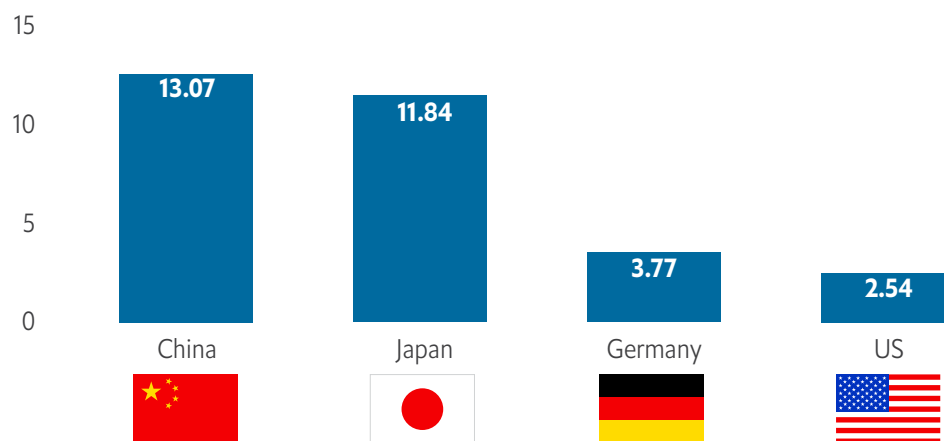


One current trend of relevance to China is the increasing utilisation of scientific sustainability practices. Fertiliser management, intercropping, intelligent crop rotation, livestock integration and reduced tilling are among the strategies now being employed to improve soil health and water quality while sequestering carbon and reducing emissions

reduced tilling are among the strategies now being employed to improve soil health and water quality while sequestering carbon and reducing emissions. “I see a lot more momentum from farmers trying to adopt some or all of these principles, and while there are a lot of barriers to adoption, I think they’re achievable”, claims Ryan Sirolli, Global Row



FIGURE 7: Total pesticide use per area of cropland
(kg/ha, 2018)



Source: Food and Agriculture Organisation (FAO), United Nations

Crop Sustainability Director at Cargill. “This will create a more resilient system that is less drought-prone and with soils that can deal with heavy rains. This, in turn, can reduce the use of purchased inputs like nitrogen fertiliser, diesel fuel and labour, generating higher margins for farmers.” The two biggest barriers to overcome, he says, are greater education and awareness, and de-risking the short-term costs.

Innovations in traceability technology are another area of progress that could prove relevant to the Chinese context. Allison Thomson at Field to Market: The Alliance for Sustainable Agriculture, a multi-stakeholder sustainability platform, believes better visibility in the supply chain is critical for improving sustainability performance. “Companies need some way to reach back out to the farmer if they don’t have a direct contract – just sourcing corn in the Midwest, there are thousands and thousands of farmers that [the

corn] could have come from.” Sustainable production requires accurate reporting and information from farmers. Field to Market provides a platform that collects field-level data and computes environmental impact for farmers, companies and other supply chain stakeholders. This allows more precise targeting of sustainability interventions, and effective reduction of environmental degradation. According to its president, Rod Snyder, the programme currently covers nearly 4m acres of the 250m total for commodity crops in the United States.

Uptake of sustainable agriculture principles among private sector players is also shaped by state-level regulation and policy, driven by rising consumer and corporate interest. In some areas, uptake of these practices has been transformative. “In the Chesapeake Bay region, a key watershed on the eastern seaboard, through a combination of regulation and cost sharing, we have seen significant adoption of no-till diverse



crop rotation and nutrient management at the highest rates in the US. Farmers have learned and adapted. Many who were skeptical or opposed to the system early on are advocates now,” says Ryan Sirolli at Cargill.



The US has nearly a hundred years of public investment in agricultural conservation through the [United States Department of Agriculture’s] Natural Resources Conservation Service, and private sector decisions to get directly engaged in environmental impact within their value chain is coming on the heels of this long history of public sector investment

To understand specific geographies of farming, research from the public sector, combined with national resource conservation programmes and NGO-sponsored farmer education programmes, has created an enabling environment for the roll-out of sustainable agriculture.¹³² Multiple interviewees identified the public sector and the government’s long history of investment in agricultural conservation as drivers of sustainable agricultural practices.

“The US has nearly a hundred years of public investment in agricultural conservation through the [United States Department of Agriculture’s] Natural Resources Conservation Service, and private sector decisions to get directly engaged in environmental impact within their value chain is coming on the

heels of this long history of public sector investment,” says Rod Snyder. “You also have voluntary conservation programs that farmers take advantage of at a pretty substantial scale. If you combine that with the supply chain efforts, there’s a much larger documented amount of activity happening around conservation, environmental issues and sustainability in the landscape.” These efforts have borne fruit in reducing unsustainable practices like pesticide usage, with the United States using far less pesticide per acre of cropland than China and Japan, and even less than Germany.

Government sets innovation finance, strategic direction and food safety standards

The federal government is a major force in shaping the country’s food system. It is a significant investor in promoting agricultural science, and shapes the overall coordination and direction of the sector through the US Farm Bill, an omnibus, multiyear law that governs agriculture and food programmes. The law includes expenditure of US\$428bn on the sector from 2019 to 2023.¹³³ This covers domains including conservation, farm payments and insurance mechanisms, collaboration with nutrition assistance programmes for low-income households, and support for the management of forest land. It has also encouraged the diffusion of renewable energy systems through grants, loans and procurement initiatives.¹³⁴ Government funding has also been forthcoming during the Covid-19 crisis. The Coronavirus Food Assistance Program, launched in April 2020, is directly supporting



farmers with US\$16bn to mitigate the impact of economic losses.¹³⁵ A further \$3bn was promised to purchase fresh produce and redistribute it to food banks and other non-profit organisations, providing food security to vulnerable people. A second round of funding, up to \$14bn, was promised in September 2020 to extend the program.¹³⁶

On the regulatory and consumer protection side, the safety of the food supply chain is largely incumbent on the manufacturing

and processing requirements of the FDA.¹³⁷ Its rules are widely enforced through tools such as factory inspections, criminal sanctions, seizures, voluntary recalls, Good Manufacturing Practices and legislation.¹³⁸ Dan Glickman, former US Secretary of Agriculture, identified the power to shut down manufacturing facilities that violate regulations through seizures and injunctions as crucial for regulatory authorities, and stated that the mere threat of enforcement was used to enhance compliance.



FDA regulations are comprehensive across the supply chain. For example, rules on pesticide use apply both at the application stage and on residues in end products.¹³⁹ Similarly, the FDA's Good Manufacturing Practices explicitly require food-processing facilities to have adequate sanitation, hand-washing facilities, and waste and offal disposal.¹⁴⁰ In contrast, food safety inspectors in China have been criticised for failing to efficiently check and audit producers.¹⁴¹ Insufficient regulatory resources and capacity have impeded progress towards food safety, despite the development of more stringent laws.¹⁴²

A robust network of NGOs and consumer groups in America also helps maintain high food safety standards in the United States. "China doesn't have as many NGOs and consumer groups, where a lot of the strength comes to point out these [food safety] problems," says Dan Glickman. "In most countries there is a strong organised consumer element that can't be neglected. Consumer influence has been helpful in ensuring that producers and food companies do a better job at food safety compliance." He notes that the centralisation of agriculture has also made managing food safety standards much easier. "The structure of agriculture in America has become much more centralised. The average farmer, producer and processing facility has all gotten bigger. This makes identifying the source of the [food safety] problem much easier," adding that, "With smaller producers, there's often less likely of an ability to identify and regulate safety violations." As China's agricultural system consolidates and centralises, it will become easier for regulatory authorities to ensure high food safety standards.

Germany: Strengthening food safety via strong surveillance systems, sustainability through consumer education programmes

Germany's food sector offers relevant practices for China in two critical domains: early and effective response to disease outbreaks, and strong sustainability engagement from large-scale food producers.

Surveillance for food-borne illness enables a rapid response

Germany's response to a norovirus outbreak, originating in berry imports from China, offers lessons in supply chain disease management and underlines the importance of well-timed food safety surveillance and outbreak investigations.

Germany has a strong institutional and technology infrastructure for disease monitoring and surveillance. The Robert Koch Institute, the federal institution responsible for infectious disease surveillance, implemented an electronic outbreak reporting system (SurvNet) in 2001. SurvNet, which organises data from over 400 local health departments, ensures continuous updating of outbreak reports and facilitates rapid linkage of apparently independent outbreaks – for example, in different states – enabling subsequent analysis.¹⁴³ In its first four years, SurvNet captured 30,578 outbreak reports.¹⁴⁴

Germany's strong surveillance system was evidenced in its competent response to a norovirus outbreak in 2012, the largest recorded food-borne outbreak in the country's history, with an estimated 11,000 cases of

gastroenteritis, predominantly in schools and childcare facilities.¹⁴⁵ Studies identified frozen strawberries shipped from China as the source, an indication of how China's internal food safety shortfalls can become global trade hazards.¹⁴⁶ Berries are exposed to noroviruses at multiple points during the production process, such as through improper watering or fertilisation.¹⁴⁷ Germany's well-developed food surveillance systems allowed the outbreak source to be identified quickly, leading to timely recall and preventing more than half of the contaminated stock from reaching consumers. Timely reporting of surveillance data was essential for the identification of the source.¹⁴⁸

Germany's strong surveillance system was evidenced in its competent response to a norovirus outbreak in 2012

In Germany, responsibility for official food control and inspection rests with the federal states, which draw up monitoring programmes for food inspection. Food chemists, veterinary surgeons and qualified inspectors conduct inspections, with approximately 400,000 samples examined annually from production and processing establishments, retail outlets, border inspection posts, restaurants and communal catering facilities.¹⁴⁹ The existence of such monitoring programmes and a well-structured surveillance system enable a prompt response to outbreaks in Germany. When a similar outbreak struck students at a school in Guangzhou, researchers concluded that food-handling practices needed improvement, and that greater attention should be paid to food handling and monitoring.¹⁵⁰

Sustainability in the private sector

German food sector stakeholders—public and private—have taken steps to improve food sustainability and limit food waste. Over 11m kilograms of food are thrown away every year in Germany, 60% of which comes from private households, 20% from grocery markets, and 17% from restaurants and cafeterias. The government's "too good for the bin" initiative informs the public of the differences between "best before" and "expiry" dates, and provides information on which foods can be eaten after best-before dates.¹⁵¹ Private sector enterprises are also working to reduce food waste. Lidl, a private supermarket chain, launched an anti-food-waste strategy in 2020, providing discounts for food close to expiration dates, as part of the company's 2030 sustainability strategy.¹⁵² Anke Ehlers, Managing Director of Corporate Responsibility International at the ALDI SOUTH Group, highlights that in its national markets, it is able to offer products at reduced prices shortly before their best-before dates and donations of food products are also made to charitable organisations.¹⁵³

The retailer is targeting food waste in the home through its "Reste Retten" ("save food scraps") campaign.¹⁵⁴ Businesses can implement such anti-food waste campaigns without requiring specific government intervention. The pandemic has also generated novel ways to tackle food waste. As lockdowns left the food service sector with unprecedented surpluses, businesses have found ways to use it and limit waste. McDonald's donated raw materials and fresh produce to local food banks, while a chef from Berlin started a movement #KochenfürHelden ("cooking for heroes")

through which restaurants delivered meals to frontline healthcare workers in hospitals and nursing homes.¹⁵⁵

This drive towards reducing food waste led by the private sector has benefited from collaborations with FoodDrinkEurope and other industry associations, according to Mella Frewen, Director General of FoodDrinkEurope,

a food and beverage industry organisation. The food and beverage industry in Europe is committed to halving food waste by 2030 in line with the UN Sustainable Development Goals. The organisation has prepared and delivered food waste prevention toolkits and food donation guidelines to help manufacturers prevent and reduce food waste, in collaboration with stakeholders throughout the supply chain.

Preparing for the future: The EU “Farm to Fork” strategy



European Commission has initiated regulations and strategies which have played a role in shaping the German food supply chain. In light of the European Green Deal, the “Farm to Fork” strategy, launched in May 2020, highlights the need for a “just transition” through developing a “robust and resilient food system” that works for producers, consumers and the planet.¹⁵⁶ This strategy focuses on all aspects of the food value chain, including food security, sustainability, food waste, safety and fraud.¹⁵⁷ It is also unique because it is the first time an EU food policy encompasses all stages of the food system, and puts consumers and producers at the centre. European consumers are increasingly concerned about the use of antibiotics, hormones and steroids in meat products, and the strategy acknowledges that concern.

Objectives and targets for 2030 include reducing the use of chemical and more

hazardous pesticides by 50%; reducing the sale of antimicrobials for farmed animals and in aquaculture by 50%; and for 25% of total farmland to be used for organic farming.¹⁵⁸ Mella Frewen, Director General of FoodDrinkEurope, a European food and drink industry organisation, highlights that the plan (Farm to Fork Strategy) charts a path towards a collaborative sustainability strategy not only within supply chains, but also with the EU, national governments and trading partners. The plan acknowledges that Covid-19 has made the EU “acutely aware of the interrelations between our health, ecosystems, supply chains, consumption patterns and planetary boundaries”. Contingency plans to ensure food supply and security during future crises are a focus of the European Commission’s strategy.¹⁵⁹ Notable in the EU plan is the reward for farmers, fishers and other operators in the food supply chain who have adopted sustainability as a part of their business.

A person in a white lab coat is operating a modern food processing machine. The machine has a digital control panel with a screen and several buttons. The person's hand is visible, pressing one of the buttons. The machine is white and blue, and is situated in a kitchen or laboratory setting. The background shows a stainless steel countertop and a sink.

China's digital infrastructure, early adoption of emerging technologies by food industry businesses, and consumer comfort with digital transactions, can all support food modernisation reforms

Section 5: Implications for China's food future

China's food system has increased output to feed a growing population, despite natural resource constraints and the pressures created by decades of fast economic growth, in terms of growing demand for protein and a wider diet. This has come with costs in terms of the negative impact of food production on the environment, and food safety shortcomings, leading to harm both to livestock and humans, of which the Covid-19 crisis is the most notable example. As illustrated in Section 2, the Chinese government has put in place policies and, along with the private sector, is starting to take steps to improve the governance, sustainability and safety of this all-important sector. In the years ahead, it will be critical to build on this positive momentum, to create a food system that can best balance productivity, environmental impact, safety and sustainability. Drawing on China's own experience, and relevant lessons from lead performers elsewhere, this report points to a number of promising avenues for further progress.

The Chinese government has a pivotal role in driving sustainable food production in the absence of substantial consumer advocacy, by increasing public awareness, engaging with farmers to promote scalable sustainable agriculture techniques, and expanding environmental certification.

The central government has shown commitment to sustainability through its Sustainable Agriculture Development Plan

and the "Returning Farmland to Forests and Grassland" project. Efforts have resulted in tangible change: the total amount of fertiliser and pesticide use has been decreasing over the past few years. The government has also introduced a national-level crop rotation and land fallowing pilot programme that covers 2m ha, and estimates suggest that 28-34m ha of annually cultivated area is currently under intercropping, a sustainable model of production. However, China remains the world's largest emitter and its farmers some of the highest users of pesticides and fertilisers. Unsustainable food production remains the most significant challenge to securing China's food future.

Further reductions in the use of harmful chemicals is one priority area. China's national crop rotation initiative, for instance, covers only a fraction of the country's cultivated land.¹⁶⁰ More support for the adoption of scalable climate-smart agriculture techniques could encourage the diffusion of best practices, including measures like reduced tillage. It is essential to include farmers in those efforts. Ensuring farmer-centric measures, co-developed with intended users, means involving them at each stage of planning and implementation. China can leverage existing networks and structures such as cooperatives, which encompass over 15% of the country's farming community.¹⁶¹

Increasing public awareness of the importance of food sustainability is a second trend. Julie Hanson, Director, Europe Division of the Global Cold Chain Alliance, highlights that consumers are increasingly conscious of the environmental impacts

of their consumption. In the US market, for instance, consumer pressure has been a significant driver of reform, with rising consumption of organic food, prompting more investment in sustainable production, according to Dr Casey Hoy, Faculty Director at Ohio State University's Initiative for Food and AgriCultural Transformation. While government and industry-wide certifications are important to standardise sustainable supply chain practices, their value stems from the importance that consumers attach to them. The growing number of consumers demanding sustainably sourced products can be charged a premium based on these certifications, creating a commercial incentive for food companies. In some cases, consumers begin to demonstrate a will to pay a premium only after they start seeing the benefits. The lack of consumer interest in paying premiums today should not preclude the development of standards that may one day help consumers distinguish between environmentally responsible products – that process can be educational in its own right.

The private sector also has a distinct but important role in the movement towards sustainability. Businesses in Germany, Japan, and the United States are enacting sustainability measures across their food supply chains, which are aligned to the emission-reduction goals outlined in the UN Paris Agreement. To date, 45 companies headquartered in Germany, 102 in Japan and 169 in the United States, have set emission-reduction targets, compared to 24 in China.¹⁶² Without private sector action, the government

commitment to the Paris Agreement may not be enough. The roles of all stakeholders – consumers, NGOs, and the private sector – are equally important.

The Chinese context differs, according to Zhou Liang, a retail industry expert, with widely varying attitudes across groups of consumers based on socioeconomic factors such as purchasing power, education levels and consumption habits that differ across regions. A significant number of consumers do not regard sustainable food practices as important for their purchases. In Japan, for instance, where there has also been less consumer pressure towards sustainability, the government has played a more active role in encouraging sustainable food practices and norms, as discussed in Section 4, and has created opportunities for consumers to make informed choices. The Chinese government has already taken some measures, such as introducing environmental certifications aligned to international standards.^{163,164} More space could be created for non-governmental actors to support public awareness and advocacy.

Smart agriculture technology is helping countries increase food production and reduce ecological harm and waste; China's technological capability could place it among the food-tech world leaders.

Robotic technology, AI, drones and the IoT are all helping producers overcome constraints



such as limited available land and workforce shortages. Digital technology is also improving sustainability and safety, including blockchain and chip-based food traceability systems, apps that match producers and consumers, and cold chain infrastructure to reduce food spoilage and disease occurrence. Mike Li of Yusen Logistics highlighted that the company is experimenting with narrowband IoT to track goods, rather than vehicles, by placing chips on the products and tracking their location and temperature through base stations. Narrowband IoT enables connecting devices that require smaller amounts of data and lower bandwidth at a relatively low cost, using little power for long battery lives.

China already has a global leadership position in emergent technologies such as AI, robotics, and drones, with significant domestic capacity to deploy next-generation innovations to the food system. Home-grown tech giants are already active in parts of the food delivery chain, a role that has increased significantly with the onset of the Covid-19 crisis.

Developments include an Alibaba platform to match suppliers with consumers, enabling food delivery in as little as 20 minutes.¹⁶⁵

Other significant steps include partnerships between tech companies and food retailers to experiment with emerging technologies, such as Baidu's collaboration with KFC China to develop facial-recognition technology to predict customers' orders based on factors including age and mood.¹⁶⁶ China's digital infrastructure, early adoption of emerging technologies by food industry businesses, and consumer comfort with digital transactions, can all support food modernisation reforms.

Capacity building at the local level can improve regulatory enforcement, while market consolidation could improve compliance.

Multiple updates to enhance food safety laws and include more specific requirements on issues like sanitation have ensured that China's food safety regulations are aligned with international standards.¹⁶⁷ However, enforcement is an ongoing challenge, recognised in the country's 13th FYP. There is a pressing need to increase the quantity and regularity of food safety inspections.

To improve implementation, it is necessary to strengthen the capacity of agencies at the local level responsible for supervision and intervention.¹⁶⁸ Although laws are set at the national level, Dr Hoy points out that they are interpreted and "actually actionable at the local level by a local health department". Along with empowering and enhancing the capacity of these local bodies, he suggests that there is a need for greater coordination between federal, provincial and local authorities on food policy. Market consolidation might also be necessary as smaller firms are harder to monitor and have lower regulatory compliance. Many of China's food production firms are small in scale, use out-of-date equipment, and have inadequate management and safety adherence. The government is attempting to address these challenges by consolidating the supply chain, particularly in the meat industry, and restructuring it to replace non-compliant small-scale units with better-resourced facilities. While large-scale, industrial meat production



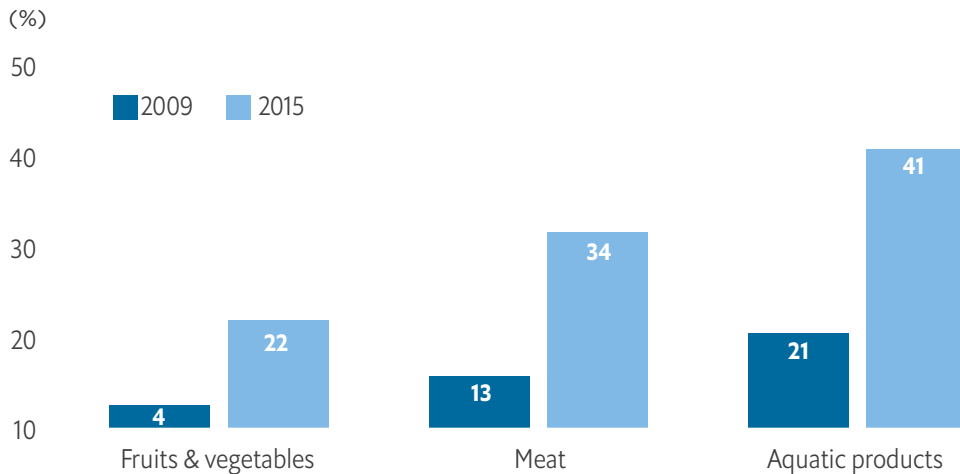
is also prone to disease; larger facilities will be subject to greater regulatory scrutiny and will have more resources to invest in biosecurity and sanitation. Competition is important in order for consumers to have choice, lower prices and better-quality products, but some degree of consolidation will resolve a much more fundamental issue plaguing the supply chain: lack of cleanliness and food safety. Other regulatory enforcement tools include swift and effective product recalls, as deployed in the United States,¹⁶⁹ and investment in disease surveillance, with a successful case study in Germany.

An inefficient food storage and transportation system carries the risk of spoilage. Strengthening the cold chain network by improving the existing standards can enhance food safety.

In 2019, over 6% of China's total food production was lost before reaching consumers, in storage, transport and processing.¹⁷⁰ FAO highlights that an efficient cold chain can assist in reducing food losses and waste and improve compliance with food safety standards, reducing health problems



FIGURE 8: Share of agricultural products entering the cold chain^{173,174}



Source: China Cold Chain Logistics Association, 2016

and costs associated with consumption of unsafe food.¹⁷¹ Total demand for food cold chain logistics in China reached 233m tons in 2019, an increase of 44.38m tons compared with 2018 (up by 23.52% year-on-year).¹⁷² According to Qin Yuming, Secretary-General of the Cold Chain Logistics Committee at the China Federation of Logistics and Purchasing, "Covid-19 is driving a shift in consumer preferences towards frozen foods, which could stimulate further sectoral growth in the future." Julie Hanson, Director at the Europe Division of the Global Cold Chain Alliance, also points out that investment funds are growing their commitment to the cold chain sector.

Expert interviewees stated that a developed cold chain network is essential to limit food safety issues in the supply chain in China, highlighting that some food companies have strict requirements for distributors to operate with cold storage. Liu Yu, Chief Operating

Officer at Xinliangji Food, claims that many products in China are still delivered using foam boxes with ice packs or dry ice, which does not provide the required temperature control to guarantee quality and safety. "In recent years, food safety accidents have occurred frequently in China, but the cold chain can effectively prevent food spoilage and ensure food quality," says Qin Yuming, Secretary-General of the Cold Chain Logistics Committee at the China Federation of Logistics and Purchasing. The cold storage of fresh products potentially minimises the risk of food-borne illnesses and reduces the growth rate of spoilage microorganisms.¹⁷⁵ Implementing refrigeration in developing countries on par with developed nations could also reduce the amount of perishable food waste annually by more than 200m tons.¹⁷⁶

A number of factors, including increasing distance between production centres and

consumers due to urbanisation, rising demand for quality fruits, vegetables, meat, fish and dairy which are perishable, and a rapid rise of supermarkets, are driving the importance of a strong cold chain network in developing countries.¹⁷⁷ Mike Li of Yusen Logistics highlights that, according to the historical experience of cold chain development in developed countries, cold chain consumption capacity and willingness will increase significantly after annual per capita income crosses a certain threshold. With the rising per capita disposable income of urban residents in China, the cold chain logistics industry begun to enter the expansion period in recent years, but the infrastructure of cold chain logistics still needs improvement.

A coherent set of industry-wide standards is missing in China, and instead there is a patchwork of over 200 overlapping standards regarding temperature control relating to agricultural products and food in China. A lack of coordination has resulted in duplication as these standards are formed and issued by different departments. These standards also lack procedures and guidance on implementation and are mostly recommendations from the government that are not mandatory or enforceable. Only 7 national standards out of the 200 are compulsory measures and it is left to a company's decision whether to follow them.¹⁷⁸ Contrastingly, in the United States, the FDA's Good Manufacturing Practices (GMP) are enforceable by law and include requirements like "an automatic control for regulating temperature".¹⁷⁹ Mandatory requirements could expand the use of temperature control and cold storage.

Uneven coverage of these standards also influences food quality and safety. These standards do not cover the entire food supply chain as they focus more on transportation and not the sales stage.¹⁸⁰ Even within the transport stage, rules are circumvented because they focus on temperatures at the beginning and end of transportation, and not during the actual transport. This loophole could be addressed by focusing on and mandating refrigeration in the entire transportation process.¹⁸¹ Industry members highlight the importance of collaboration across the supply chain to ensure the cold chain is a complete system from the farm to the consumer's fridge.¹⁸² "An enhanced regulatory and policy environment, via greater involvement of enterprises in the formulation of industry standards, is one way for China to enhance its cold chain network", says Qin Yuming, Secretary-General of the Cold Chain Logistics Committee at the China Federation of Logistics and Purchasing.

Effective operation of a cold chain system requires specific knowledge and skills.¹⁸³ Evidence from developing countries points to a lack of knowledge of proper cold chain practices, even when adequate infrastructure exists.¹⁸⁴ The need for training and education of employees involved in cold chain operations in China was underscored in the Global Cold Chain Summit in Dalian.¹⁸⁵ Addressing this knowledge gap through capacity building including training in technical knowledge and handling practices can support better handling of cold chains. Once implemented, a continuous evolution of these programmes is essential to meet the fast changing food supply chain.¹⁸⁶



China's meat supply chain faces particular sustainability and safety challenges. Plant-based meat and protein alternatives are an increasingly popular option among some Chinese consumers. Supportive policies and incentives can help the sector scale up as part of a food security and sustainability strategy.

China's meat industry is at the source of many safety challenges, including ASF, which revealed to consumers the low levels of hygiene in the pork supply chain. The meat sector is also a major environmental liability; nearly 31% of emissions from the food industry and supply chain stem from livestock directly, and 22% from livestock management, such as animal feed.¹⁸⁷ Current levels of meat consumption are unsustainable, and according to Nick Halla from US plant-based meat manufacturer Impossible Foods, "failure to pivot to plant-based diets will result in ecological collapse, which will in turn exacerbate food insecurity." "Animal farming occupies half of the ice-free surface of the planet", he explains, and this "land-footprint is preventing carbon capture".

Plant-based and artificial meats are a safe, secure and sustainable alternative. The sector is expected to grow to almost 20 times its current size in the next decade, driven by growing consumer awareness about the environmental impact of meat production.¹⁸⁸ Chinese consumers are more accepting of alternative meat products than some other large markets due to concerns about food

safety – a trend accelerated by Covid-19 and ASF.¹⁸⁹ Plant-based and artificial meats can increase food output without the land utilisation and emissions associated with livestock. This is because they enhance protein-use efficiency. Mr Halla explains that protein content in global soy crop exceeds the annual intake of protein worldwide. However, much of this protein is wasted during meat production: it takes 30 kilograms of feed to create a single kilogram of beef.¹⁹⁰ It would be much more efficient and sustainable to consume this protein directly – through plant-based meat, for example. This idea is attracting sizable commercial investment: Impossible Foods has raised a total of US\$1.5bn since its inception while choosing to remain privately held.¹⁹¹ Another plant-based meat company, Beyond Meat, listed publicly last year and now has a market capitalisation of US\$11bn.¹⁹² These US companies have trained their sights on the Chinese market, which Mr Halla calls "a very important market for us [Impossible Foods] ... where we can make the biggest impact".

China's government is stimulating this market, with national standards on artificial meat currently under development according to Qiao Xiaoling, a member of the Chinese People's Political Consultative Conference (CPPCC) and the chief engineer at China Meat Research Centre.¹⁹³ Further stimulus, such as financial support, subsidies and consumption-encouragement measures, could help the sector, as could measures like including plant-based meat in school meal standards. The success of plant-based alternatives as a food safety intervention will

also depend on cold chain infrastructure for storage and transport. Laboratory testing suggests that meat products and their plant-based counterparts are almost equally susceptible to the growth of harmful bacteria and microorganisms and must be stored at similar temperatures to prevent spoilage.¹⁹⁴ Fiscal measures could also increase the price of conventional meat to better reflect its externalities and drive consumers towards

more realistic prices required for a genuinely sustainable food system. In 2019, for instance, German lawmakers proposed increasing VAT on meat products from 7% to 19% because of their impact on the environment. Such an aggressive step could reduce meat consumption more quickly and significantly. China has also set targets to reduce meat consumption, and its nutritional standards recommend reduced consumption.





China's food system has scaled up production to meet the needs of a growing and increasingly affluent population, but this evolution has come with costs



Section 6: Conclusion

China's food system has scaled up production to meet the needs of a growing and increasingly affluent population, but this evolution has come with costs – notably environmental degradation – and has been uneven across sectors, with significant challenges in areas like food safety and standards adherence. The food system is subject to multiple shocks which can have far-reaching effects, even beyond national borders, from zoonotic diseases linked to the food system to extreme weather events like flooding. Pests and locusts are also a threat, the severity of which could increase due to unpredictable interactions between temperature and insect dynamics.

The Chinese government, food producers and the private sector have acted at multiple levels to address past and present challenges, including utilising technology to overcome existing challenges of limited land and fighting locust invasions with preventive management systems. China can also look to the examples of many countries around the world that have faced similar challenges, from the United States, where the government has been a significant investor in agricultural science and enforcement of standards, to Japan, where the private sector has utilised smart-farming technology to reduce input use and automate processes. Technological capabilities present in China can support the deployment of measures to address concerns including food waste and food safety. Strengthening the existing cold chain standards by including training and capacity building of stakeholders, implementing consistent standards and avoiding duplication of regulations can improve the cold chain network. Similar to China, Germany has faced disease outbreaks linked

to food supply chain practices. The presence of an electronic outbreak monitoring and surveillance system in Germany leads to quick recalls, prevents infected batches from reaching consumers, and ensures continuous monitoring. Lessons from Japan, which has used technology to match surplus food in restaurants with consumers looking for reasonable food via food-sharing apps, can be effective in further addressing the food waste challenge. Indeed, the Chinese government has made food waste a priority with the ongoing Clean Plates campaign.

In the United States, regulatory agencies have sufficient capacity and access to a range of enforcement tools, including product recalls, seizures and injunctions, to help ensure high food safety standards. Expanding the capacity of Chinese regulatory agencies could improve compliance with food safety rules, particularly at the local level, where much of the enforcement takes place. Greater consolidation of the food industry may be required, however, to reduce the number of small, non-compliant firms: the government has acknowledged the problem and is taking steps in this direction. Supporting sustainable food innovation segments such as plant-based meat alternatives is another potential avenue that could help the country consolidate its progress and work towards a balanced, safe and productive food system for all.

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