FOOD SAFETY IN CHINA: A MAPPING OF PROBLEMS, GOVERNANCE AND RESEARCH

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LIST OF ACRONYMS

AQSIQ	Administration of Quality, Supervision, Inspection and Quarantine
BOD	Biological oxygen demand
CDC	Center for Disease Control
CHNS	China Health and Nutrition Survey
COD	Chemical oxygen demand
CFDA	China Food and Drug Administration
CSA	Community supported agriculture
DDT	Dichloro-diphenyl-trichloroethane
GAIN	US Department of Agriculture Global Agriculture Information Network
GAP	Good Agricultural Practices
GMP	Good Management Practices
HACCP	Hazard Analysis and Critical Control Points
HCH	Hexachlorocyclohexane
HM	Heavy metal
MEP	Ministry of Environmental Protection
MOA	Ministry of Agriculture
MOH	Ministry of Health
OCP	Organochlorine pesticide
POP	Persistent organic pollutant
SAIC	State Administration of Industry and Commerce
SFDA	State Food and Drug Administration
WTP	Willingness to pay

EXECUTIVE SUMMARY

Food safety has become an issue of great concern in China over the last few years. Media reporting has tended to focus on extreme cases of poisoning from food additives or contamination by heavy metals, but food safety encompasses a wide range of problems that occur at different points in the chain from the production to the consumption of food. The risks involved vary widely from product to product and present very different kinds and levels of threat to human health from sources including bacteria, viruses and parasites, chemicals, growth hormones and veterinary drugs. This report examines what we know from research in the natural, medical and social sciences about the nature and causes of these problems, and about the current state of policy and societal responses. It aims to inform the more effective use of existing knowledge and the development of a more integrated and problem-oriented research agenda.

Problems, drivers and trends

Rapid economic growth, significant increases in agricultural productivity and changing patterns of consumption over the last 35 years have transformed the production, distribution and consumption of food in China. On the one hand, hunger has more or less been eliminated and people have access to a wider range of food products than before, but concerns about food security and malnutrition remain. At the same time, new food safety problems are emerging that reflect strains on China's food system stemming from processes of urbanization and industrialization, including the intensification of agricultural production, the rapid expansion of certain product sectors, longer supply chains, and the consumption of more processed food. These interact with intense market pressures, a widespread lack of social trust, and inadequate regulatory capacity to make food safety a challenging governance issue.

Many of these problems were also encountered by developed nations during their periods of intense industrialization and urbanization, but because these processes have been more compressed in China, food safety problems are manifesting themselves in a more extreme form. However, China's development pathway has also had some unique characteristics, and certain policies and administrative arrangements (including land tenure, rural industrialization, central-local fiscal and administrative relations, etc.) have shaped both the nature of food safety risks and the capacity to respond to them. Food safety also interacts with several other policy agendas, including the development of the food industry, food security, nutrition and health, and environmental protection.

Uneven development and regional diversity mean that China has not one food system but many, with different scales and modes of production coexisting and intersecting. Complex interactions between different drivers of food safety problems mean that different parts of the country, and different food industries, face particular constellations and flows of risks. Consumption patterns, which vary by age, gender, region and ethnic group as well as by socio-economic status, also affect the nature and degree to which specific populations are exposed to various risks. As a result, no simple association can be made between socioeconomic status or regional economic development and levels of risk. Wealthy consumers have more purchasing options, but they may also be exposed to a greater number of risks through longer and more complex supply chains, while some poor areas have relatively safe local food systems. Overall, uneven economic development means that relations between richer and poorer parts of China mirror to some extent those between rich and poor nations in the global context.

Four Issues in Focus

This report illustrates the complexity of food safety in China through four examples: heavy metal pollution, pesticides, veterinary drugs and food additives. These relate to different stages of the food supply chain, involve different actors, and present different challenges for governance. In each case we present a summary of existing knowledge regarding the nature and extent of the problem, its drivers and related policies.

Contamination of food by heavy metals—particularly cadmium, lead, mercury and arsenic—is of great concern because it affects staple foods including rice and vegetables and has severe health effects. The presence of heavy metals in the food production environment can be due partly to high background levels, but is often caused or exacerbated by pollution from mining, industry, pesticides and animal feed. Soil degradation resulting from intensive agriculture also makes heavy metals more bioavailable to crops and is a serious problem in many parts of China. However, because different crops and varietals also have different propensities to accumulate heavy metals, soil quality is not a direct indicator of the risk through food. Reducing food safety risks from heavy metals therefore requires different approaches in different locations depending on the nature and severity of the problem, and calls for the involvement of several policy streams including environmental protection, agriculture and land resources.

Pesticide residues and veterinary drugs both represent cases in which food safety risks have emerged as side effects of the intensification of agricultural production. The rapid increase in agricultural productivity has been accompanied by an increase in the use of chemical inputs, and the overuse of pesticides in particular is recognized to be a serious problem. It is attributed to farmers' lack of information about effective and safe levels of application, cheap prices, consumer demand for attractive food, and the promotion of pesticides by

agricultural outreach stations. With the rapid development of the livestock and aquaculture sectors, the use of veterinary drugs has also increased and these are often given to animals, fish and poultry not only to treat disease but also for prophylactic purposes and to promote growth. The overuse of veterinary drugs is an issue of particular concern from a long-term public health perspective because it contributes to the genetic selection of antibiotic resistant bacteria (ARB), which may render ineffective drugs commonly used to combat disease in humans as well as animals.

Food safety problems relating to additives involve both excessive use of allowed food additives and the use of illegal or non-sanctioned chemicals in food production. Additives are used for a variety of reasons, including increasing aesthetic appeal, extending product life and adding weight or apparent nutritional content (as in the case of melamine). The increased use of additives is driven by the increase in consumption of processed food, and to some extent by consumption of food outside the home. As with the sale of fake or inferior food products, the issue of additives in food to some extent resembles product safety and quality problems in other manufacturing sectors. However, the number of substances, production facilities and retail outlets involved makes the food industry particularly hard to regulate.

Governance

As a late industrializer, China has the advantage that risks to health through food are now quite well-understood scientifically, and international standards have been established for safe levels of the dietary intake of many substances. However, some of these standards will need to be adapted to the Chinese context because of different dietary and consumption patterns. Similarly, China can reference the regulatory systems and mechanisms that have been developed by other countries to deal with health risks from food. However, these systems represent "finished products" that are the result not only of lengthy processes of political bargaining and policy development but also of scientific, regulatory and administrative capacity building.

Over the last several years, the Chinese government has rolled out a series of policy initiatives to address food safety problems, both as a new policy domain and under the mandate of existing policy streams including agriculture, environmental protection, and health. Some of these policies involve new standards relating to production environments and processes, as well as permissible levels of potentially harmful substances in food. Others involve the introduction of mechanisms for improving traceability and accountability through vertical linkages along the food supply chain or the scaling up of production and processing operations. Recent reforms have consolidated responsibility for food safety under a new China Food and Drug Administration.

However, substantial investment in human resources will be necessary to ensure the implementation of these measures, and there has yet to be much evaluation of the effectiveness of different approaches under different market conditions. Overall, improvement on many food safety problems is likely to take time, and it is unlikely that a "one size fits all" approach will be effective across product sectors and jurisdictions. Because many of the drivers of food safety problems lie beyond the mandates of the agencies responsible for enforcement, cross-sectoral collaboration will be key. In particular, there needs to be greater consideration of the way in which policies designed to monitor and enforce product safety interact with policies to promote product development, and with market incentives and consumer willingness and ability to pay. The implications for food safety of industrial restructuring that is encouraging the movement of industry into China's hinterland and West also need to be considered.

Public demand for improvements in the management of food safety risks is increasing faster than the capacity to provide them. It is fueled partly by the media focus on problems that involve acute outbreaks of food-related illness and on diseases like cancer that have a high "dread risk" factor, as well as by growing awareness of the impacts of environmental degradation on health more generally. Public anxiety is heightened by the lack of reliable public information or risk communication, and by evidence of official corruption associated with some food safety problems. Although the need for greater public oversight is recognized, there is a lack of formal mechanisms, such as consumer associations, to enable it.

Research

Research on food safety in China is in its early stages and the field is very fragmented. It is characterized by a combination of aggregate data and small case studies, neither of which provides an accurate picture of the actual risks to which particular populations or localities are exposed. Research from different disciplines and systems uses different samples and methods, and cannot be easily matched or analyzed in an integrated way. With the exceptions of rapid-onset illnesses and the Total Diet Study (TDS), health data do not enable the isolation of health risks of food from other pathways of exposure. Environmental quality or input data are therefore often used as a proxy for health impacts, giving a misleading impression of the prevalence of some risks, for example those from heavy metals. More generally, sampling frames for regular environmental quality and health monitoring do not reflect the distribution of the drivers of food safety risks.

While there are some in-depth studies on particular industries, including milk, beef, and aquaculture, most research on food safety does not link up to analysis of broader changes in the food system. Social science research in particular has mostly been reactive in focusing on product lines that have experienced high-profile problems rather than taking

a systematic approach to understanding the drivers of food safety problems and the challenges they present for governance.

Policy research is especially scant, and policy recommendations tend to be limited to general calls for stronger enforcement and collaboration, with little consideration for different regional needs and capacity levels, or evaluation of the effectiveness of policy interventions in different contexts. In all countries there is to some extent a tension between food safety considerations and cost, and this is more pronounced in emerging economies such as China where the price of food is still a concern for many people. A better understanding of price-safety interactions and the ways in which different policies might affect them will be important in ensuring that the whole population has access to safe and affordable food.

1. INTRODUCTION

Food safety has become an issue of enormous public concern in China in recent years, generating an avalanche of new policy initiatives as well as an array of different efforts, especially by urban residents and institutions, to better understand and control the sources and quality of their food. This report examines what we know about the nature and causes of the various problems that comprise "food safety" in China, and about the current state of policy and societal responses, drawing on research from across the natural, medical and social sciences. It aims to inform the more effective use of existing knowledge and the development of a more integrated and problem-oriented research agenda.

Given the wide range of problems and policy systems involved, this report does not attempt to be comprehensive but rather to sketch major issues and developments. The analysis draws on a number of reviews prepared by researchers with expertise on particular topics, individual and group discussions with these and other academics in the field, and reading of key articles and reports in the Chinese and international literatures. In the interest of space we have referred where possible to review articles rather than to individual studies. A full list of references consulted is available on request.

It should be noted that many aspects of food safety have yet to be thoroughly researched and the rapid evolution of both problems and policy responses means that much information is quickly out of date.

2. THE LANDSCAPE OF FOOD SAFETY IN CHINA

2.1 Classifying food safety problems

Food safety in China, as elsewhere in the world, is characterized by "an abundant array of hazards" (FAO/WHO, 2006, p. 3) that can be categorized in a number of ways. This report uses a systems approach and we therefore distinguish food safety risks in terms of the point at which they occur in the chain from production to consumption.[1] Table 1 provides an overview of the landscape of food safety problems in China and the products they affect.

This listing reflects the way in which food safety problems are commonly discussed in China, and results in a hybrid scheme in which some problems relate to products, some to type of contaminant and others to the medium or mode of entry into the food chain. These categories are not mutually exclusive: for example, the problems presented by out-of-date food often involve bacteria, and some pesticide residues and animal feeds contain heavy metals. This kind of mixed classification is also common to the World Health Organization (WHO) Committees on Food Safety which include some related to product types (Meat Hygiene), some to particular substances (Contaminants) and others to types of inputs (Pesticides) (FAO/WHO, 2006). [2]

One question raised by these hybrid categories is how they relate to possible ways of differentiating the nature and severity of various food safety problems. From a public health perspective, it is important to consider whether health impacts are acute or chronic, communicable or non-communicable, localized or widespread, and direct or mediated through ecosystems. For example, the development of Antibiotic Resistant Bacteria (ARB) resulting from the overuse of veterinary drugs, which threatens to render many types of widely-used antibiotics ineffective on a global scale, is arguably the issue of greatest concern, while the nature and severity of other risks such as food additives or heavy metals vary considerably depending on the particular chemicals, exposure levels and sizes of populations involved. Risks might also be distinguished in terms of whether the substances concerned also cause threats to health through other environmental media such as air and water, as in the case of heavy metals, and whether they have long-term impacts on ecosystems as well as human health.

It is also important to understand the way in which classification schemes relate to the interests of various stakeholders and how they intersect with agency mandates and

1.See Garnett and Wilkes (2014) for a broader application of the food system approach to China.
2.Elsewhere, FAO/WHO (2006, p.2) classify food safety risks according to whether they stem from biological, chemical or physical hazards.

Table 1: Food safety problems by product type and stage of food system

Stage of food safety	Production Environment	Production Process				Production Process Point of Sale		Transportation and Storage Point of Sale	All
Product problem	**HMs and industrial**	**Pesticide residues**	**Unhealthy animal feed**	**Antibiotics**	**Growth Promoters**	**Additives**	**Fake products**	**Rotten/Out of date products**	**Bacteria, Viruses,**
Grains									
Rice	•							•	•
Wheat								•	•
Other								•	•
Meat									
Beef		•	•	•	•	•		•	•
Lamb							•	•	•
Pork		•	•	•	•	•		•	•
Poultry			•					•	•
Vegetables									
Melons					•	•		•	•
Leafy green	•	•			•			•	•
Root								•	•
Beans	•	•						•	•
Aqua products	•		•	•				•	•
Dairy				•	•	•		•	•
Fish	•		•	•				•	•
Fruit		•			•	•		•	•
Oils						•		•	•
Processed foods						•	•	•	•

administrative structures, as well as evolving policy and programmatic priorities (for example, food security and nutrition policy) and related resource allocations. These intersections (and dislocations) between policy priorities and competencies influence the ways in which various government agencies frame and engage with food safety problems, and contribute to synergies and gaps in policy responses (Holdaway, 2011). Some of these are discussed with regard to particular agencies and issues below, but further analysis would help to illuminate where some of the specific barriers to interagency collaboration lie.

2.2 China's food safety problems in global perspective

Considering how China's food safety problems relate to international experience is helpful in distinguishing which of the regulatory challenges involved are generic to the issue area and which to China's particular development pathway and governance system. Comparison may also be useful for understanding the timeframe in which China can be expected to develop regulatory capacity with regard to different problems.

Obvious comparisons can be drawn with the history of the United States and Europe where food safety was also an issue of intense concern during the periods of most rapid industrialization and urbanization (Global Food Safety Forum, 2011; Han, 2007; Nestle, 2003; Collins, 1993; Barkan, 1985; Sinclair, 1905). Population movement combined with growing specialization of production and longer supply chains separated consumers from producers, leading to a lack of knowledge of, and anxiety about, the origins of food and its safety. Meanwhile, the increase in consumption of processed food and food eaten outside the home provided opportunities for bacterial and chemical contamination, the introduction of illegal additives and the sale of fake products. In a situation where the pace of change outstripped the development of regulatory capacity, and traditional relationships of trust based on the proximity of producers and consumers had not yet been replaced by impersonal regulatory systems in which people had confidence, anxiety about fraud and other kinds of food safety ran high (Collins, 1993; Barkan, 1985) .

As in China today, it seems that the first food safety problems to attract strong public attention (as early as the 18th century in Britain and the late 19th century in the US) were those that had rapid onset and either involved clearly criminal behavior or caused diseases like cancer that have a high "dread risk" factor (Slovic, Fischhoff, & Lichtenstein, 1979). This included primarily hygiene-related problems and the use of illegal additives (Collins, 1993; Barkan, 1985). Because slower-onset problems like the health impacts of heavy metal pollution from industry and mining were less well understood and less easily discerned by the public, they did not become a concern until considerably later, with a second burst of regulation in the early post-war period. By this time, Europe and North America were in a position to upgrade pollution control and many polluting industries subsequently closed

or relocated.[3] The widespread use of synthetic fertilizers and pesticides, and growing understanding of the consequences of the buildup of these chemicals in the ecosystem, were also part of the second wave of public concern and regulation. Veterinary drug use and its implications for the development of resistant microbes is an even more recent issue in Europe, and some of these drugs have yet to be regulated in the US.

Public concern about bacterial contamination and food fraud appears to have declined in Europe and the US as national food safety legislation was introduced to regulate conditions in processing plants and mandate testing of food products. Although there is critical analysis of the focus and efficacy of these measures (see Nestle, 2003), they reduced the incidence of outbreaks resulting from domestically sourced food. At that time, trade in food products from poor countries tended to be limited to dry goods or those that were not easily perishable, and meat, fish and fresh fruits and vegetables were sourced either more locally or from other rich countries with similar storage and transportation capacities and regulatory regimes.

These problems have now resurfaced as transportation and storage technologies as well as improved communications have made it possible for food to be sourced globally, and demand for non-local and non-seasonal foods has increased. The result is that rich countries now buy large quantities of food from countries whose production and inspection processes they cannot control (GFSF, 2011). This has generated demand for international standards regarding food safety, and international bodies (primarily the World Health Organization (WHO) and the Food and Agriculture Organization (FAO)) have been tasked with establishing them.

Considering food safety on a global level shows that there has been an evolution of problems, of our understanding of them, and of the development of regulatory capacity at different levels of governance (local, national, global). Many of the food safety challenges that China is now facing are similar to those faced by developed countries during their periods of industrialization and urbanization. Similar also is the gradual shift from risks associated with hygiene and fraud toward those associated with the intensification and industrialization of food production, with the expansion of the food processing and catering sectors, and with longer and more complex supply chains that connect jurisdictions with different levels of capacity for monitoring and enforcement. However, because these processes have been more compressed in China, some problems are more extreme and present a greater challenge for governance in terms of the need to develop regulatory capacity very rapidly.

At the same time, the size and uneven development of China, the diversity of conditions for food production and variation in the drivers of problems means that different areas

3.The last primary lead smelter operating in the US, founded in 1892, was scheduled to close in December 2013 because it could not meet new, stricter pollution control standards

are experiencing different constellations of risks, and relations between richer and poorer parts of China to some extent mirror those between rich and poor countries in the global context. This adds an additional challenge for policy, which needs to be responsive to different patterns of risks and take into consideration different levels of capacity for managing them. However, China's food safety problems cannot be understood only as a function of its level of economic development; they also have particular characteristics that reflect China's specific development pathway and governance system. Nor is there a simple relationship between level of development and exposure to risk, as some poor areas have relatively safe local food systems.

China is at an advantage over the early industrializing nations because the health impacts of food-related health hazards are better understood scientifically and international standards for dietary intake have been developed. But some of these standards need to be adapted to the Chinese context because of different dietary patterns (for example, the importance of rice) and differences in the production environment. Similarly, China has the opportunity to reference the regulatory systems and methods developed by other countries to deal with health risks from food. However, many of these regulations and mechanisms represent "finished products" that are the result not only of lengthy processes of policy development but also of scientific, regulatory and administrative capacity building (see, for example, accounts of the introduction and enforcement of food safety-related regulations in Britain and the US in Collins, 1993, and Barkan, 1985). These processes will also take time in China, and will likely move faster in places with stronger human and financial resources. As a result, it seems likely that progress in addressing food safety risks will be uneven across regions and product sectors.

As in many other policy areas, public demand for improvements in the management of food safety risks has risen faster than the capacity to provide them. This demand has an international dimension in the sense that the regulatory systems of developed nations provide a reference point for public expectations in China that did not exist when these countries were themselves experiencing similar problems.

2.3 The evidence base: data and research on food safety in China

Appendix 1 contains a longer discussion of research and data sources, but a few points deserve emphasis here. Although it is a rapidly growing field, food safety is a new topic of research in China and there is a lack of reliable data to enable an assessment of the scale and distribution of many problems. The field is very fragmented and characterized by a combination of aggregate data and small case studies, neither of which provides an accurate picture of the actual risks to which particular populations or localities are exposed. Research from different disciplines and systems uses different samples and methods, and cannot be easily matched or analyzed in an integrated way.

With the exception data on rapid onset illnesses and the Total Diet Study, most health data do not enable the isolation of health risks from food from other pathways of exposure. As a result, environmental quality or data on agricultural inputs are often used as proxies for health impacts. But because many intervening factors determine whether or not pollution or inputs generate risks to health through food, this can give a misleading impression of the prevalence of problems. More generally, sampling frames for regular environmental and health monitoring do not reflect the distribution or trends in the drivers of food safety risks.

More importantly, while there are some in-depth studies on particular industries—particularly dairy and beef—most research on food safety does not link up to research on broader changes in the food system and therefore cannot inform forward-looking policy-making. Social science research in particular has mostly been reactive in focusing on product lines that have experienced high-profile problems rather than taking a systematic approach to understanding the drivers of food safety problems and related governance systems.

While there is a great deal of commentary on the new laws and policies that have been introduced in the last few years, there has been very little systematic analysis of their implementation and effectiveness. Research on regional variation in food safety problems is minimal, and evaluations of the effectiveness of existing policy and assessments of the investments in human resources and equipment needed to achieve results within different time frames appear to be entirely lacking.

In this context, media and NGO reports play a key role in shaping public perceptions of the scale and nature of food safety problems, as they do with other environmental issues (Liu, Dong, Wang, & Shishime, 2011; Dong, Ishikawa, Liu, & Hamori, 2011). However, media reports tend to emphasize certain problems over others, with a preference for crisis situations and problems with a high "dread risk" factor (Slovic et al., 1979) over less dramatic problems. This causes certain risks to loom particularly large in the minds of the public. To the extent that the government itself is also struggling with a lack of data, it may also influence policy priorities.

The lack of reliable data on both the prevalence of food safety problems and governance capacity contributes to the lack of public trust and exacerbates the tendency for debates about food safety to become polarized between those who see the main problem as a lack of political will, official corruption and/or the decline of public morals, and those who view food safety problems as stemming largely from China's status as a developing or transitional country with limited resources and capacity.

Although the WHO, the EU, the World Bank, the International Development Research Centre and other international actors have begun to engage in this area, international collaboration has yet to make a big contribution to understanding China's food safety

problems. As in other policy areas, both academic research and government reviews of international experience sometimes seem to be driven more by who the international partners are than by a systematic appraisal of which experience is most relevant to China. Collaboration has also primarily been with developed country governments and research agencies. While more thoughtful analysis of how China can learn from the experiences of the early industrializing countries would be helpful, global management of food flows may also offer ideas about how to improve food safety in the context of uneven development, as would the experience of the other BRIC countries experiencing similar processes (Holdaway, 2012).

3. DRIVERS AND TRENDS

3.1 Generic and China-specific drivers

The FAO/WHO (2006) Guide to Food Safety Risk Assessment identifies eleven factors influencing national food safety systems, shown in Table 2 below. This list relates primarily to changes in the production, processing, trade and consumption of food. Transformations have taken place across all these dimensions in China over the last 35 years. Agricultural production has expanded rapidly, with grain productivity doubling since 1980 (Carter, Zhong, & Zhu, 2012). There have also been large increases in the production of higher value livestock and aquaculture products, and horticultural produce. The gross output value added of crop production grew at 2.9% per annum over the last 30 years, while the aquatic and fisheries sector grew by 6.8% and livestock by 5.9% (Carter et al., 2012). For a detailed analysis of changes in China's food system, see Garnett and Wilkes (2014).

Table 2 Changing global factors affecting national food safety

* Increasing volume of international trade.
* Expanding international and regional bodies and resulting legal obligations.
* Increasing complexity of food types and geographical sources.
* Intensification and industrialization of agriculture and animal production.
* Increasing travel and tourism.
* Changing food handling patterns.
* Changing dietary patterns and food preparation preferences.
* New food processing methods.
* New food and agricultural technologies.
* Increasing resistance of bacteria to antibiotics.
* Changing human/animal interactions with potential for disease.

Source: FAO/WHO (2006, p. 3).

These large gains in productivity have been attributed to the development of high-yield grains and an increase in the use of inputs in the horticultural sector, and in the livestock

sector to the scaling up of production and the introduction of new animal feeds and genetics (Carter et al., 2012). As production has expanded it has become more specialized and more geographically concentrated, and overall there has been a shift from mixed crop-livestock farming to monocultural agriculture.

The food processing industry has also seen rapid expansion and diversification and is now a major contributor to GDP, with certain product sectors seeing particularly rapid growth. The processed food market was valued at US$ 140.4 billion in 2011, with dairy registering the highest retail sales, followed by bakery and dried processed foods (Bradbury, 2012). In addition to the expansion of domestic markets, international trade in food, both imports and exports, has also increased over this period (Garnett and Wilkes, 2014).

These changes in production have been mirrored by changes in consumption and purchasing patterns. Overall spending on food has increased, although it now accounts for a smaller proportion of total household expenditure in both rural and urban areas. Consumption of meat, eggs, dairy products, and aquaculture products has increased, as has that of processed foods, as well as sugars, confectionery and soy products, fruit and alcohol. Consumption of grains (especially coarse grains), tubers, vegetables and legumes has been declining (Cao et al., 2013).

Food retailing has also seen significant change, with traditional wet markets now coexisting with an increasing number of large and small supermarkets. While general retail sales grew at 10% per year in the 2000s, the supermarket sector grew by 30% and supermarkets accounted for about 30% of urban food retail sales by 2004 (Zhang & Pan, 2013). More food is also consumed outside the home in restaurants, fast food outlets and at street stalls. Out-of-home food consumption grew 159-fold in the 30 years between 1978 and 2008 (Hawkes, 2008).

In broad terms, this means that in addition to "traditional" risks related to hygiene, the last 35 years have seen the emergence of new food safety risks associated with the intensification of agriculture and the scaling up of the aquaculture, livestock and dairy sectors as well as with the production of more processed food, the transportation of food over longer distances, and the proliferation of different retailing and catering outlets (Han, 2007). Although other nations have experienced similar problems to varying degrees, a number of influencing factors deserve particular emphasis in the China context. These include extremely rapid but uneven economic growth; demographic change, including urbanization; declining fertility and ageing; pollution and degradation of the agricultural production environment; and patterns of land tenure and industry structure.

The governance challenges associated with food safety as a policy domain are discussed in detail in Section 6. However, food safety concerns also interact with existing policy agendas including food security, nutrition and environmental protection. Section 3.6 briefly discusses these interactions.

3.2 Rapid but uneven economic growth

China has experienced remarkably high rates of economic growth over the last three-and-a-half decades, with both rural and urban per capita incomes increasing more than six-fold and the nation as a whole reaching middle income status. However, large pockets of absolute poverty remain, and there is serious inequality on many indicators of human development along the lines of region, urban-rural status and gender (World Bank, 2009; UNDP, 2010). In 2008, the per capita GDP of Shanghai was nearly ten times that of Guizhou, and literacy rates in the wealthy coastal areas were almost 15% higher than in the poorest western provinces (UNDP, 2010). Both overall, and within regions, rural incomes are lower and access to health, education and other services is poorer than in urban areas. Although their life expectancy is longer, women have higher rates of infant mortality and illiteracy than men (UNDP, 2010).

Greater prosperity has a number of implications for food safety. On the one hand, higher incomes have caused changes in dietary patterns, including increases in consumption of meat, dairy products and processed food and in the frequency of eating outside the home (see Garnett and Wilkes, 2014). In the context of inadequate regulation and enforcement, this brings greater risk of exposure to problems associated with these products and industries. However, rising incomes also offer consumers more choice and increase the demand for higher quality, safer products both directly through purchasing decisions and indirectly through pressure for more effective regulation. Both of these trends are evident in China.

The unevenness of China's development creates difficulties that affect most issue domains, and the food sector is no exception. On the one hand, food production has expanded enormously over the last 35 years, hunger has more or less been eliminated and people have access to a wider range of food products than ever before. Yet concerns about food security and malnutrition for some population groups persist, and ensuring an adequate supply of affordable, nutritious food will remain a priority for some time to come. These old concerns with food security must now be balanced with new issues that stem at least to some extent from China's very success in increasing the supply of food. These include not only food safety concerns related to the intensification and industrialization of production, but also environmental impacts and new health problems associated with over-rich diets (for an in-depth discussion of these linkages see Garnett and Wilkes, 2014).

Although the food sector evokes strong emotional responses due to its intimate connections with personal health, family life, rural livelihoods, and cultural identity, many of the challenges involved are not unique to this issue. Across many economic sectors, China is attempting to upgrade and more tightly regulate production and consumption in some parts of the country in order to develop higher value products, improve quality and safety, and reduce environmental impacts while at the same time stimulating production and consumption (of lower value products) in other areas in order to reduce inequalities in

income and access to goods and services.

Policy must walk a delicate line between conflicting priorities, and measures introduced to address one issue may have unintended consequences or differential impacts across regions or economic groups. In the food sector, this means that tensions exist between ensuring the quantity of production, its quality (not only safety but also nutritional value and environmental impacts) and equity considerations in terms of the distribution of benefits and costs across regions and populations. These interactions are explored further in the discussion of particular food safety issues below.

Policy is also challenged to keep up with the sheer pace of change, and institutional and human capital development inevitably lags even further behind. Regional diversity in both the nature of problems and in the financial and human resources for addressing them also makes developing and enforcing national standards extremely hard. In terms of food safety, uneven development means that patterns of consumption, as well as the ways in which food is produced, transported and stored vary widely, as does the potential for upgrading the food supply chain. Capacity for government oversight and regulation, and consumers' access to information and ability and willingness to pay also differ greatly both across and within regions.

However, this does not mean that there is a simple relationship between poverty and the prevalence of food safety risks. Wealthy consumers have more choice and can buy imported foods and expensive domestic brands. But they may potentially also be exposed to risks through longer and more complex supply chains, while some poor areas have quite safe, localized food systems. As with environmental impacts on health at the global level (Smith & Ezzati, 2005), it may be that middle income, rapidly transitioning areas are the ones that face the greatest risks overall (Holdaway & Marshall, 2010). Further analysis of the relationship of price to safety and of regional differences and inter-regional interactions is needed in order to better understand the nature of problems and responsive capacity in specific contexts. To date, however, most discussion has been focused either on national policy or on specific product lines, with little attention to regional variation and cross-jurisdictional flows of risk.

3.3 Demographic change

The spatial distribution and age composition of China's population have undergone profound changes in the post-reform period. Demographic change, including urbanization, decreased fertility and population ageing have the potential to affect food safety through their impact on the agricultural environment and methods of production, as well as through changes in diet, demand for certain types of food, and willingness and capacity to pay.

From a low base, China's urban population has increased steadily over the last 30 years,

from 191 million in 1980, to 636 million in 2010; the United Nations projects that it will be over a billion by 2050. The urbanization rate passed 51% in 2011, up from 19% in 1979.[4] The total number of cities in China grew from 193 in 1978 to 655 in 2008, and the number with more than 1 million people from 13 to 58. The urban built-up area increased fivefold between 1981 and 2008 (Yeh, Xu, & Liu, 2011).

Urbanization in China has had some particular characteristics. Rural industrialization, policies to promote the development of small and medium-sized cities and controls on internal migration have meant that a substantial percentage of the population has urbanized in place. At the same time, employment incentives generated by industrialization and the expansion of the construction and service sectors, along with overall regional income differentials and the gradual relaxation of controls on movement have also stimulated rural-urban migration on a massive scale, mostly from the poorer western provinces of China to the wealthier coastal regions. Official statistics report that there were 211 million rural-urban migrants in 2009, and this is expected to rise to 350 million in 2050.

Rural-urban migrants are generally between the ages of 20 and 45 and work in production, construction, wholesale and other service sectors (National Population and Family Planning Commission, 2010, cited in Yeh et al., 2011). In general, migrants are lower paid, work longer hours, and live in worse housing conditions than local residents. Although the policy has been modified in recent years, rights to settlement, and access to public services and certain types of employment are still tied to a person's residence registration (hukou), which specifies both an administrative jurisdiction and rural/urban status. Although whole family migration is becoming more common as access to education in urban areas becomes easier, many migrants maintain two households, sending remittances home to support children and elderly parents in the countryside or county towns, further reducing their disposable income.

The other major demographic changes in the post-reform period have been a dramatic fall in fertility and population ageing. Official statistics show a fertility rate of only 1.6 (World Bank, 2011) and much of the population born after population control policies were introduced in the 1980s grew up as only children. Meanwhile, life expectancy has risen to 73 years and this, in combination with lower fertility and changes in population structure, is causing rapid population ageing. The share of the population aged 60 and above is now at 12%, but is predicted to rise rapidly and reach 31% by 2050. Out-migration has concentrated young people of working age in urban centers and left a higher share of the elderly population and in some cases also young children in rural areas (Banister, Bloom, & Rosenberg, 2010).

The physical growth of cities and towns has swallowed up vast tracts of land formerly

4.An urbanized area is defined in China's 2000 census as one with more than 1500 people per km². Different measures of the urban population have been used over time, but since 2000 China has adopted the standard definition of six months residence (Yeh et al., 2011).

used for agriculture, putting greater pressure on remaining arable land (Chen, 2007). In combination with changes in livelihoods, the concentration of the population in cities and towns has removed millions of people from the direct production of food. In 1970, 80% of the workforce was engaged in agriculture; by 2009 only 38% was employed full or part-time in the primary sector (Carter et al., 2012) Urbanization has stimulated whole new industries of commercial food production, processing, transportation and retail, and is also a major factor in the stretching of food supply chains and the increase in consumption of more processed food and food eaten outside the home.

To the extent that regulatory capacity fails to keep up, rapid urbanization is likely to increase food safety risks related to these practices. However, there will be differences across and within regions. Newly urbanizing areas with poor infrastructure and regulatory capacity are likely to experience more problems, while more established urban populations are increasingly making demands regarding public information and regulatory performance on food safety. Well-resourced cities are introducing measures to control supply chains in much the same way that importing nations do on the global level.

Demographic changes are also affecting the organization of agricultural production in ways that may affect food safety. The combination of population ageing, urbanization and industrialization is reducing the labor force available for agriculture, which must compete with industrial and service sectors for the shrinking number of workers. Even if they remain in the countryside, many working-age people have already left, or never worked in, agriculture. In combination with out-migration, this means that farming is now often the responsibility of women with young children and the elderly, or is conducted in short bursts when migrants return for planting or harvesting. Although only one factor among many, the lack of full time adult farm labor contributes to the use of labor-saving chemical fertilizer and pesticides (SAIN, 2012; CCICED,2010). As some areas become centers of intensive agriculture, in others people are being pushed off the land by urbanization or are becoming day laborers for large producers who have contracted their fields. These changing patterns of labor force participation affect the use of inputs and incentives to engage in safe or sustainable cultivation practices in complex ways which are not yet well understood (Holdaway, 2014).

Because patterns of food consumption vary considerably by age, demographic shifts and changes in the spatial distribution of age cohorts may also affect demand for certain food products and ability to pay. For example, migrants are a potentially vulnerable population in the urban context because their low incomes, long working hours and poor housing conditions limit their choices in terms of what they eat and how it is prepared. Migrants' extreme sensitivity to price most likely contributes to the demand for cheap food at the expense of quality, while their economically marginal position means that they are obliged to work in the informal sector or as small scale vendors (Yeh et al., 2011), which are regarded as contributing to unsafe production and processing practices.

3.4 Pollution and degradation of the food production environment

One negative side effect of China's rapid economic growth has been severe environmental pollution from industry and high-input agriculture. In 2011, 39% of water monitored in the major river systems and 57.5% of that in major lakes was Grade IV or below, and 55% of ground water was reported to be of "bad" or "extremely bad" quality (MEP, 2012). As much as 10% of arable land is reported to be contaminated with heavy metals to some degree and soil is severely degraded from prolonge d and heavy use of farm chemicals (Chen, 2013; CCICED, 2010). In December 2013, the vice minister of Land Resources, Wang Shiyuan, reported that 50 million *mu* of farmland had medium or serious levels of pollution, mostly in areas that have been centers of heavy industry including the Yangtze and Pearl River Deltas, the Northeast, and parts of Hunan (Xinhuanet, 2013).

The health effects of pollution generally are becoming increasingly clear and generating significant concern. Because China's development strategy encouraged rural industrialization (Bramall, 2007), pollution of the agricultural production environment by industrial waste and attendant risks through food is more severe than in some other countries. Pollution from agriculture is now also recognized to be a serious problem, and accounts for a larger share of total emissions than does industry (MEP, 2012). Almost half of the impressive increase in grain productivity since 1980 has been attributed to inputs (FAOSTAT, 2013): use of chemical fertilizers increased five-fold, with similar trends in the application of other agricultural chemicals, such as pesticides, fungicides and herbicides, and in the use of plastic sheeting (Carter et al., 2012). With the exception of heavy metals in animal feeds and heavy metals and other toxic chemicals in pesticides, pollution from agriculture is generally a more serious problem for drinking water safety and agricultural sustainability than it is for food safety. However, over-intensive agricultural practices also contribute to degradation of soil that increases the risk that heavy metals will affect crops.

Although statistics are often reported for the nation as a whole, pollution has strong regional and local characteristics as a result of the nature and intensity of the industrial and agricultural activities involved, and these need to be understood in order to assess food safety risks in particular locations. For example, heavy metal pollution from mining and related industries is quite geographically concentrated (see Chen, 2013), and there are also significant regional variations in the use of pesticides (see sections 4.1 and 4.2).

In recent years, stronger environmental protection policies along with industrial upgrading and transfer have reduced pollution emissions in early-industrializing areas, but legacy pollution continues to present a problem for safe food production. Meanwhile, new areas may be at risk as industries move into the hinterland and western parts of the country in response to market forces and government policies designed to mitigate uneven development (CCICED, 2012a). Land zoning policies that designate certain areas for agricultural production, industrial development or ecological preservation will interact with economic and political incentives in complex ways (Liu, 2011).

Analysis of existing environmental quality can be helpful to some extent in assessing the distribution of food safety risks and identifying priority areas for intervention. However, particularly in the case of HM pollution, it is important to avoid a simple extrapolation from environmental quality indicators to food safety. This is because the extent to which HMs present a risk through food depends not only on the specific metals involved and their concentrations, but also on other factors including soil quality, climate and the nature of the crops grown (Chen, 2013). From the point of view of prevention, it is important also to consider the deeper drivers of food safety problems in local patterns and trends of economic development, and their impacts on the environment and human health (Holdaway, 2014; Holdaway, 2013).

3.5 Land and industry fragmentation

Both land holdings and production structures (farming, industry) are highly fragmented in China, and this is seen by a majority of analysts to be an underlying cause of food safety problems, impeding scale production, technical upgrading and branding (Han, 2007). Government policy largely reflects this framing, with consolidation frequently pursued as a response to the discovery of food safety problems. However, it should be noted that large-scale producers have by no means been exempt from food safety problems, and indeed were thoroughly implicated in the 2008 melamine incident (Pei et al., 2011; Xu & Klein, 2010). Analysis of the beef industry also suggests that consolidation in the absence of the necessary market conditions and regulatory capacity can exacerbate rather than reduce food safety problems (Waldron, Brown, & Longworth, 2010; Brown, Longworth, & Waldron, 2002). The basic premise of the dominant analysis that the modernization of Chinese agriculture must entail aggregation and industrialization is also strongly contested by advocates of small-scale, integrated food production who argue that large-scale, industrial agriculture is not sustainable from the perspectives of either the environment or livelihoods (for example Wen, 2008; Shi, Cheng, Lei, Wen, & Merrifield, 2011).

The fragmentation of both land holdings and industry reflects key features of China's development model, and interacts with food safety in complex ways. With the dissolution of collective farming in the late 1970s, land use rights were granted to rural households. While this stimulated rapid growth in agricultural output, at least initially, and contributed to rural economic growth, it also resulted in a high degree of fragmentation of land holdings. The vast majority of agricultural production is carried out by around 200 million smallholders working on holdings with an average size of 0.6 hectares (see Keeley, 2013). From the point of view of food safety, small-scale agricultural production with low levels of technical expertise and capital investment is thought to preclude technical upgrading, such as advanced control of application of inputs (FMFACP, n.d.; Li, 2009). Much analysis of food quality and safety has been framed as a question of supply chain upgrading, with policies encouraging the penetration of high-value supply chains into rural areas in

order to increase vertical supply chain integration and raise standards (Waldron, Brown, & Longworth, 2006).

Certain policies have contributed to the continued fragmentation of rural land holdings and inefficiencies of scale. First is the prohibition on the sale of farmland: policy has instead attempted to enable consolidation of rural land through various rental and transfer arrangements (see Huang, Wang, & Qiu, 2012). The 2013 Number One Document envisages strengthening of land rights as a means of supporting development of large-scale family farms and agricultural cooperatives (Keeley, 2013),and recent policy announcements indicate that the future direction of reform in land rights will enable farmers to transfer or mortgage their contracted land and to convert land use rights into shares in large-scale farming operations (State Council, 2014). At the same time, rural collective land is to be allowed to enter the market for construction land, paving the way for a unified land market. But implementation arrangements are still being elaborated and change is likely to be incremental rather than sudden, setting a limit to the speed with which large-scale agricultural holdings can be developed. Another factor that limits consolidation is the government commitment to maintaining small farmers' access to markets for reasons of welfare and livelihoods (Waldron et al., 2006). This likely limits the compliance-related costs that can be imposed on smallholders before they are forced out of markets, and therefore the rapidity of policy change.

Marketing and processing of agricultural produce tend also to be fragmented. Marketing is dominated by small scale, mobile traders, who purchase products from villages and small farms and bring these to market (Gale & Hu, 2012). Agricultural processing also tends to be conducted by small companies: according to data from the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ), in 2007 China's food processing sector included more than 448,000 businesses, of which almost 353,000 had fewer than ten employees and many had inappropriate business licenses and or no license at all (Thompson & Hu, 2007). While the total market share of these small businesses (at less than ten percent) is relatively small, they are believed to contribute many of the greatest food safety challenges (United Nations in China, 2008; Han, 2007), having little access to capital or technology and little awareness of relevant food safety standards and procedures. The mobility of small companies, and the speed with which they enter and exit markets, also create difficulties for adequate oversight (Li, 2009; Thompson & Hu, 2007). Fragmented production and processing make development of traceability systems difficult and adulteration of foods hard to detect (Gale & Hu, 2012; Han, 2007).[5] More broadly, industry fragmentation may result in highly competitive markets in which pressure to cut costs leads to unsafe practices in the absence of adequate regulation and enforcement.

5.All data cited here are likely changing very fast, as land consolidation efforts, development of cooperatives, policies on increasing oversight of small producers, etc., take hold.

3.6 Intersecting policy systems

Food safety is increasingly seen as a distinct area of policy, and related initiatives are discussed in Section 5. This section highlights a number of other policy streams that are particularly important in shaping food safety in the Chinese context.

Food security policy. The emphasis on food security (*liangshi anquan*) that has dominated agricultural policy in China intersects with the promotion of food safety in a number of ways.[6] The policy of maintaining 95% grain self-sufficiency has focused on maintaining the area of land under cultivation: the current target is 120 Mha.[7] But industrialization, infrastructure and property development are driving the conversion of agricultural land to other uses. The incentives for this are strong, as infrastructure and property development can contribute as much as 30-50% of local government revenue and are important contributors to economic growth, which continues to be the primary measure of local government performance (Norse, Lu, & Huang, 2012). The conversion of productive agricultural land to non-agricultural uses, combined with a central requirement that any land converted to non-agricultural uses be offset by reclamation of land elsewhere, may result in agriculture's being pushed out from productive land to more marginal and/or polluted land. More generally, the pressure on arable land generates incentives to raise yields by higher use of chemical pesticides or high-yield crops, which in some cases also have a higher propensity to absorb heavy metals.

Nutrition and health policy. The health sector has been given significant responsibility for policy initiatives relating specifically to food safety policy. However, broader health and nutrition policies also have implications for food safety that may have reinforcing or countervailing effects. For example, the focus on addressing obesity, diabetes and other diet-related non-communicable diseases in the 12th Five-Year Plan is leading to a greater focus on educating the public about the benefits and risks associated with various foods (World Bank, 2011). This is likely to have positive effects in terms of raising awareness about safety. However, the introduction of nutritional and quality standards can sometimes have unintended consequences as producers competing in tight markets or seeking greater profits may use fraudulent methods to meet those standards (as in the case of melamine added to milk to mimic the effect of higher protein content). New nutritional guidelines may also lead to sudden stimulation of demand and rapid increases in production of certain products in the absence of adequate safety measures and regulatory capacity.

Environmental protection policy. A fundamental difficulty in improving food safety problems that stem from pollution of the production environment is that responsibility for

6.Arguments and data in this section are based principally on Norse et al. (2012).
7.Although there is debate as to actual areas of cropland in China, largely stemming from issues of measurement and reporting (Norse et al., 2012) land available for agricultural production is both limited and of poor quality: less than 10% is suitable for crops and around two thirds is not highly productive (Norse et al., 2012). Land available for conversion to agricultural use is very limited.

regulating soil and water quality is spread across the Ministry of Environmental Protection (MEP), the Ministry of Land Resources, the Ministry of Water Resources and the Ministry of Agriculture (MOA), which have various, and sometimes overlapping, responsibilities (see World Bank, 2006, for those relating to water). The general trend has been towards an increase the number of pollutants controlled and the sites at which they are monitored, and the introduction of progressively stricter standards. While initial monitoring and regulation focused mostly on water and air pollution, soil pollution and household waste have now been added to the list. The 12th Five-Year Plan has also seen a shift toward a focus not only on aggregate emission levels but also on the control of priority pollutants that are particularly damaging to health (including heavy metals) or implicated in climate change. However, environmental monitoring is not yet well adapted to assess the impacts of pollution on health generally, and this is also true of impacts through the food chain (Holdaway, 2013; FORHEAD, 2010; Su & Duan, 2010).

More generally, the amount and quality of land available for food production is affected by a number of policies that relate to land zoning and land-use planning. Policies and measures relating to these emanate from a number of different agencies and are not well integrated (Yeh et al., 2011). At the highest level, Main Function Area Planning (*zhuti gongnengqu guihua*) designates broad regions and sub-regions for optimized development, key development, restricted development and prohibited development (Liu, 2011). Refining and implementing this policy is emphasized in the 12th Five-Year Plan, and the need to make fiscal transfers and evaluation criteria reflect the capacity and needs of different regions is explicitly discussed (CCCPC, 2011). However, strong tensions exist between local economic development and environmental protection, particularly in the poor provinces of western China (CCICED, 2012a).

Other policies. The development and implementation of food safety policy is also shaped by broader aspects of governance, as well as by the division of regulatory responsibility and fiscal resources across levels of government that affect most policy domains (see section 5.5.2 for a discussion of central-local relations). Legal development, including that of tort and related laws, is highly relevant to food safety problems that involve criminal behavior as opposed to the overuse or inappropriate use of legal substances. Public understandings of food safety problems and levels of trust in government risk communication will also be affected by changes in law and policy relating to access to information and transparency.

4. FOUR ISSUES IN FOCUS

Since it is not possible to cover the full range of food safety problems in this short report, we have focused on a number of issues that reflect problems occurring at different stages in the food supply chain and which raise different challenges for governance: heavy metal contamination; pesticides; veterinary drugs and additives.

4.1 The production environment: heavy metals

Among China's food safety problems, contamination of the agricultural production environment by heavy metal (HM) pollution stands out as a problem that is more severe than in many other countries. HM pollution can be caused by mining, metal smelting and industrial processes, and also through the application of certain pesticides and manure from animals whose feed contains HMs. Cadmium is seen as presenting the greatest risk because it affects staple foods—in particular rice and leafy vegetables—has high mobility and causes serious health problems, primarily affecting the bones and kidneys (Chen, 2013). Because of its impact on children's cognitive development, lead is also a serious concern (Zhang & He, 2009), as are mercury, arsenic and chromium in some locations. Some heavy metals, including lead, can have indirect health effects through their impact on crop yields.

HM pollution of the agricultural environment in China is the result of a number of factors that interact in different ways in different locations. One factor has been rapid industrialization, and in particular the penetration of industry into rural areas that has marked China's development pathway (Bramall, 2007). Even when the area affected is not large, and the percentage of aggregate emissions is low, the effects of rural mines and industries on the health of local populations can be very severe (Su & Duan, 2010). Soil in areas with rich mineral deposits generally also has high background levels of HMs. Regardless of whether the presence of HMs in soil is natural or results from human activity, its uptake by food crops is affected by a number of other factors, including soil acidity and organic content, climate, and the type of crops planted (see below).

The Total Diet Study (TDS) provides some information on HM pollution levels in foods, although only a few results are publicly available. Cadmium intake has shown a steady increase, reaching 40mg in 2007 (the FAO/WHO standard is 60mg), and smaller studies have shown intake levels in particular places to be considerably higher, reaching acute levels in some cases (Chen, 2013). To some extent the TDS data can be used to identify products and regions with high levels of HM contamination (Li, 2012). However, because the sample is based on dietary variation rather than the distribution of environmental drivers, and includes only three sites for each province, the extent to which the findings

represent the national or even provincial situation is doubtful. A number of smaller case studies have found excessive levels of HMs in rice, vegetables and aquaculture and meat products (for example Shi, Li, & Pan, 2009; Cheung, Leung, & Wong, 2008; Fu et al., 2008; Chi, Zhu, & Langdon, 2007).

In the absence of comprehensive food data, most discussion of food safety risks from HM pollution has tended to extrapolate from information about levels of HMs in soil. The most commonly cited statistics come from the special investigation on soil pollution launched in 2006 by the MEP and the Ministry of Land and Resources. The results have not been published, and were recently declared to be a national secret (Shanghai Daily, 2013). However, the head of the MEP, Zhou Shengxian, said in July 2006 that 12 million tons of crops were polluted with HMs each year, causing direct economic losses of 20 billion RMB; that 150 million *mu* of arable land were polluted to some degree, and 32,500,000 *mu* irrigated with polluted water and 2 million *mu* covered in solid waste, for a total affected area amounting to over one tenth of China's arable land (cited in CCICED, 2010).[8] In December 2013, the vice minister of Land Resources, Wang Shiyuan, reported that 50 million *mu* of farmland had medium or serious levels of pollution, mostly in areas that have been centers of heavy industry including the Yangtze and Pearl River Deltas, the Northeast, and parts of Hunan (Xinhuanet, 2013).

These statistics have caused great consternation, but their implications for food safety and public health are in fact far from clear not only because the amount of land affected is disputed (due to sampling frames and density), but also because the level of contamination in different places, the specific metals involved and the fates of the contaminated crops is not known (Chen, 2013). The Ministry of Agriculture has recently initiated a province-by-province soil survey specifically focused on food safety that should provide much more detailed information: Guangdong alone will take 50,000 samples (Chen Nengchang, personal communication, March 21, 2013). Findings from another large survey of soil quality in eastern and central China conducted by the Ministry of Land and Resources will be published in the first quarter of 2014.

In the meantime, a number of small-scale studies have tested crops in situ. However, some of these studies were conducted to confirm the presence of suspected problems in areas close to or downstream from mines or factories (for example Zhuang, McBride, Xia, Li, & Li, 2009; Fu et al., 2008; Wong, Li, Zhang, Qi, & Min, 2002), and others to assess the potential for "green" or "no harm" agriculture in places where contamination was likely to be relatively low (e.g. Jin, Li, Pan, Wu, & Liao, 2007). What they provide is therefore probably a sense of the extremes of the distribution.

The situation is complicated by the fact that the presence of a certain level of HMs in soil is not an accurate indicator of health risks through food. The accumulation of HMs by crops

8.One *mu* is equal to approx. 667 square meters or one fifteenth of a hectare.

is affected by climatic conditions and by the acidity, organic content and moisture level of the soil; different types of crops and cultivars also have different propensities to absorb HMs. These factors interact in complex ways. For example, China has lower background levels of cadmium than Japan, but because over half of China's arable land is short of microelements, phosphorus and potassium, and the organic content is much lower, HM uptake rates are often higher and crops can be unsafe even when levels of HMs in the soil are within permissible limits (CCICED, 2010; Chen, 2013).

Because local diets and crop cultivars vary considerably, different regions will also have different levels of exposure even with the same level of HMs in soil. For example, Japonica rice, which is more commonly grown in the Northeast of China, has a lower tendency to absorb cadmium than Indica, which is more common in the South, and different cultivars and hybrids of the same plant also have very different uptakes of cadmium. Field studies of rice have found that, depending on soil conditions, differences in cultivar type can make the difference between whether or not cadmium levels are within safe levels (see Shi et al., 2009). In some areas, deficiencies of zinc, iron and calcium, which contribute to the absorption of cadmium, increase the risk (Chen, 2013). Because of the importance of rice and leafy greens in the Chinese diet, China's standard for acceptable levels of cadmium in food is stricter than international standards (at 0.2mg Cd/kg, compared with 0.4 mg Cd/kg).

Given the complexity of health impacts, the lack of good data and the way in which markets redistribute risks, it is impossible to make a full analysis of which populations are most exposed to HM pollution through food. However, it seems that severe risks are fairly localized to people living in the vicinity of mines and industries, or markets into which products from these places are sold. This is why Hunan, which is a major rice producing and exporting province but also one with large mineral reserves and related extractive and processing industries, has become a target of HM risk management policies. Guangdong, a major importer of Hunan rice, banned purchases from the province in 2013 after the Guangzhou Municipal Food and Drug Administration and the Provincial Food Safety Office found excessive levels of cadmium in rice on sale in markets and restaurants (Pang, Gong, & Liu, 2013).

Other populations are probably exposed to much lower levels of risk. It is not necessarily the poorest regions or people that are the most vulnerable, as some very poor areas have no industrial pollution and relatively fertile soil in which people continue to grow most of their own food, while others are heavily contaminated by mining or industrial pollution and have soil that may or may not also be seriously degraded from years of intensive agriculture, making HM more mobile and easily absorbed by crops. At the same time, rich areas may have a history of industry that has left serious legacy pollution, as in Guangdong. The way in which various kinds of pollution interact with the types of crops that are planted and dietary habits, as well as how much food is home-grown or bought, will also produce patterns of risk that cut across income levels; this is also clear from the analysis of the TDS

(Li, 2012). That said, within any given context, affluent consumers or their suppliers will be more able to purchase selectively. Table 3 shows the role of different environmental and social factors in determining the distribution of risks from HM pollution in food.

Soil pollution prevention was included in, but not a focus of, China's first Environmental

Table 2: Heavy metal pollution and food safety: severity and distribution of health risks

Drivers	Factor	Concentration in soil	Uptake by crops	Human Intake	Local Impacts	Broader impacts
Naturally occurring high levels of minerals	High background levels of HMs	•	•			
Mining or industry in vicinity or upstream	Proximity of pollution source	•	•			
Scale and duration of production	Level of emissions	•	•			
Presence or absence of pollution control						
Acid rain	Salinity of soil	•	•			
Fertilizer use						
Precipitation level and groundwater situation	Moisture level of soil	•	•			
Past fertilizer use	Fertility of soil (organic content)	•	•			
Over intensive cultivation						
Zinc, iron, etc. or other heavy metals	Interaction with other elements	•	•			
Rice and leafy greens higher uptake	Type of crop		•			
Certain rice cultivars have higher uptake	Cultivar		•			
Regional diets	Quantity consumed			•	•	
Alternative food sources						
Nutrient deficiencies	Health status			•	•	
Age, sex, genetic profile of population						
Surplus production	Sale of contaminated food outside production area					
Awareness of risk						•
Regulation at point of sale						

Protection Law in 1979. The 1989 Law on Environmental Protection contained further provisions, but soil pollution did not become a priority until the early 1990s (CCICED, 2010). The 1995 Standard for Soil Environment Quality sets three levels of standards for land in ecological protection zones, for agricultural production and for forestry, including HMs and pesticides including DDT (GB 15618-1995). Standards for irrigation water set acceptable levels of total Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and HMs, and general water quality standards apply to natural water supplies that are used for agriculture, although these are not routinely tested. For naturally occurring water, Grade III and above is classified as safe for common (but not rare) species of fish, and Grades IV

and V for general agricultural purposes. However, depending on the levels of particular chemicals, Grade V water might exceed standards for irrigation water (GB 5084-2005).

In addition to specific environmental quality requirements, the government is also acting to separate industry from agriculture and residential areas and make pollution control more effective (and cost-effective) through land-use zoning. At the macro level this is evident in Main Function Area Planning (*zhuti gongnengqu guihua*) introduced in the 11th Five-Year Plan, that designates particular regions and sub-regions primarily for agricultural production, and some for ecological protection, while "optimizing" and prioritizing industrial development in others (Liu, 2011). At the county level, the impact of environmental protection policies is evident in the closing of small mines and industries and the concentration of others in industrial parks. However, there are many challenges to the implementation of these zoning regulations at a time when both market incentives and regional planning policies are encouraging the relocation of industry to the hinterland and West of China (CCICED, 2012a; CCICED, 2012b).

Remediation of many large sites is planned or underway. But one difficulty for remediation is that the scarcity of arable land in China makes it hard to take large areas out of cultivation in order to remove and replace the topsoil as was done in the US, Europe and Japan. The cost of doing so on the scale required would also be prohibitive. Therefore, although Superfund-style remediation projects in which contaminated soil is being removed and replaced are being undertaken in some areas—including Hunan Province—efforts are also being made to find ways to improve food safety in the short term, by detoxifying the soil through phytoremediation, fixing HMs in the soil, reducing absorption by planting different crops or cultivars, or improving the soil (Chen, 2013). In the meantime, testing of rice and other products sensitive to HM contamination is increasing and some areas found to be producing crops containing excessive levels have been ordered to stop production (Pang et al., 2013).

As with other issues, the HM pollution problem also interacts both with concerns about food security and with the development of particular product lines. In the case of rice, for example, policy has focused on developing and promoting high-yield, Indica-Japonica hybrids ("super rice"), but unfortunately some of these also have a high propensity to absorb cadmium and also have lower uptakes of zinc, which is beneficial to health (see Shi et al., 2009). Because the choice of crop or cultivar can make the difference between whether food is safe for consumption or not, these interactions need to be considered, especially in areas known to be at high risk of HM pollution.

All these policies should help to reduce HM risks through food if they can be implemented effectively. Therefore, although public anxiety about HM contamination is rising and very serious problems remain, an overall reduction in risk is probably already underway in early industrializing parts of China. However, the transfer of industry and potential to exploit the extensive mineral reserves in western China presents concerns that pollution may spread

there (CCICED, 2012a; CCICED, 2012b). Environmental impact assessment requirements will need to be strictly followed if food safety risks are not to result.

Meanwhile, the health system will need to deal with the impacts of chronic exposure to HMs for some time to come, a task for which it is currently not well-equipped. Although China has a comprehensive system for the monitoring of infectious diseases, monitoring of exposure to HMs is not a routine task of Centers for Disease Control and Prevention and they have few resources available for this. Incorporating regular testing, particularly of vulnerable populations such as children and pregnant women, would seem to be a priority in order to identify and address problems early (Fang, Wang, & Luo, 2014; Holdaway, 2013; Fang, 2012).

4.2 Production process: pesticides

China is both a major producer and the world's largest consumer of pesticides. In 2010 there were more than 1,800 pesticide producers, and usage increased more than 2.4 times between 1990 and 2010 to reach over 17 million tons (see Cai, 2013; Sun et al., 2012). However, as with HM pollution, aggregate and average statistics disguise considerable regional variation. For example, the mean application rate of 8.19 kg/ha in 2001 obscured averages rates of 12.91, 7.26 and 3.43 kg/ha in East, Central and Western China, respectively (Sun et al., 2012). In 2010 the highest use was in Shandong, Hubei, Henan, Hunan, Anhui, Jiangxi, Guangdong, Jiangsu, Hebei and Heilongjiang, which are the largest producers of cereals, cotton, fruit and vegetables, have the most commercialized agricultural sectors and are relatively wealthy (Sun et al., 2012).

Overuse of pesticides is recognized to be a major problem. Studies have found that insecticide application rates are often 2-3 times the recommended dosage (Ma et al., 2000; Li, Zhang, Gon, He, & Norse, 2006). As a result large quantities of pesticides enter the soil or surface water and residues remain on crops. Like HMs, pesticides can enter the food chain through drinking water as well as through food. Most attention has focused on crop residues, which are related not only to the amount of pesticide used but also to the timing of application.

Efforts to increase agricultural production for direct consumption and animal feed have driven higher levels of inputs. Heavy fertilizer use itself can lead to greater use of pesticides, as can monocultural agriculture that reduces natural predators and the physiological resistance of plants. Overuse is also attributed to lack of information about effective and safe levels, cheap prices, and the promotion of pesticides by agricultural outreach stations (Sun et al., 2012). The greater range of crops being grown and the wide range of pesticides available make it more difficult for farmers to be informed, and perceived or actual insecticide resistance can lead farmers to apply greater quantities (Sun et al., 2012; Fang, 2012).

Organochlorine pesticides (OCPs), which include hexachlorocyclohexane (HCH) and dichloro-diphenyl-trichloroethane (DDT), were originally the major concern until they were banned in 1983. By 1985 an estimated 14 million hectares of farmland were above national standards (Sun et al., 2012, citing Lin et al., 2000). But again there were big regional variations, with average concentrations of DDT in East China 14 and 5 times that of those in South and Southwest China, respectively, and concentrations of HCH in the South and Southwest 4 and 2 times as high as those in the North (Sun et al., 2012). Concentrations are generally higher in the North than in the South, probably because of water shortages, with the highest concentrations in the Yellow and Huai River basins. Other studies have detected traces of OCPs in water (Wang, Yuan, & Gale, 2009) and soil (Li et al., 2006).

Data on health effects of pesticides through food are quite limited. The most comprehensive information comes from analysis of the 2007 TDS. One study found Persistent Organic Pollutants (POPs) in 9 of a total of 12 major food groups bought from markets, grocery stores and farms and prepared according to local recipes from rural and urban areas in 12 regions of China. However, it found that DDT and HCH concentrations in foods had decreased from previous studies and that dietary intake levels were below safe levels (Zhou et al., 2012). OCPs were found primarily in aquatic products, meats and cereals.

However, averages again obscure differences in levels of different pesticides in different regions and foods (Zhou et al., 2012). As with HMs, the TDS broadly confirms the patterns that one would expect on the basis of patterns of agricultural production and dietary patterns. For example, levels of HCH are higher in aquaculture products in the North than in the South (Li, 2012). Quite a number of smaller studies have found POPs in human blood, serum and breast milk (see Lau et al., 2012 for a summary). However, as with HMs, these cannot provide the basis for generalization beyond the study sample. So far there appear to be few dietary studies for phosphorus-based pesticides, and very little research has been done on the new generation of pesticides (Cai, 2013).

Other studies have tested products at the point of sale. Although policies are now in place that call for systematic testing (see below), studies (e.g. Ma, 2012) suggest that testing for pesticide residues is intermittent at best. The largest published study, from 2001, reports data from the National Quality Inspection Agency showing that of 181 vegetables in 10 major groups tested in wholesale markets in 23 large and medium sized cities, 86 (47.5%) had pesticide residues at levels that exceeded national standards. Other studies are limited to particular provinces or cities and show excessive levels of pesticide residues on rice, vegetables, meat, bean and aquaculture products ranging from as low as 7.8% to as high as 67% (see Cai, 2013, for a summary). Some studies have found residues of prohibited pesticides including DDT (Wang et al., 2007). Other studies have found pesticides in vegetables (Yu et al., 2009), and in fish and mollusks (Liu et al., 2010). Like the diet studies, this research shows that a serious problem clearly exists with certain products in certain places, but also that there is considerable variation by region. A study by Greenpeace (2011)

of food bought in a number of urban supermarket chains suggests that some companies are able to manage their supply chains more effectively than others (see the section on policy below).

In terms of trends, the use of low-residue and less toxic pesticides is increasing, and the Institute for the Control of Agrochemicals, Ministry of Agriculture (ICAMA) reports that bio-pesticide sales are growing at a faster rate than chemical pesticides (ICAMA, 2012). There are also new concerns: herbicides used to clear ground around orchards, chemicals used to promote germination and growth and the use of pesticides in greenhouse gardening are on the list of emerging issues of concern to environment and health risk experts (Wang, Fang and Li private communications, February, 2013). Production statistics also suggest that these may be emerging problems: of the three major types of farm chemicals, insecticides are falling as a percentage of output, while the percentage of anti-bacterials and herbicides has grown from 10.1% and 28.6% and from 7.1% and 45% over the same period (China Pesticide Industry Council, 2011). Research on farmers' pesticide use suggests that many different chemicals are now being used in various combinations (Fang, 2012).

Policies have addressed pesticide use on a number of levels, including overarching attempts to encourage harm-free and organic agriculture, tighter regulation of the certification of new pesticides and policies designed to bring pesticide use down to safer levels. ICAMA was established in 1963, and DDT and other highly toxic pesticides were banned in 1983. In 1997, the State Council issued Regulations on Pesticide Management, which were revised in 2001. China has ratified the Stockholm Convention of Persistent Organic Pollutants, which went into effect in 2004, and in 2005 set up a National Coordination Group for Implementation of the Stockholm Convention consisting of 11 ministries and agencies (Lau, Leung, Wong, Wang, & Yan, 2012).

Pesticide POPs are regulated by the Ministry of Health in terms of their levels in food and by the Ministry of Agriculture in terms of certification, labeling and use. 2008 saw the introduction of Measures for the Implementation of the Regulation on Pesticides Administration, and Measures for the Administration of Pesticide Labels and Manuals (see Lau et al., 2012, for a list of relevant laws and standards). All new pesticides now have to be registered with ICAMA. Recent measures have focused more closely on health and on food safety, with the Ministry of Health and Ministry of Agriculture establishing Maximum Residue Limits (MRL) for 12 pesticides in food in 2010 as part of the national food safety standards (ICAMA, 2012). In 2012 the Ministry of Agriculture introduced a formula for calculating Acceptable Daily Intake (ADI) levels for pesticides based on lifetime ingestion (ICAMA, 2012).

China has had programs to encourage agricultural production with reduced use of farm chemicals since Ecological Agriculture (*shengtai nongye*) was introduced in the early 1980s. The development of certification for organic and minimally treated food began in the 1990s and has had a complicated history with both the Ministry of Agriculture and the

Ministry of Environmental Protection playing a role. A variety of different names have been used over the years, but currently three standards are in use. "Organic" indicates no pesticides or toxic chemicals have been applied for at least two years for annual crops and three years for perennials, with annual inspections and no tolerance for GMO. "Green Food" is comparable to integrated crop management with limited use of farm chemicals, but also has different grades, the highest of which (AA) is comparable to organic. "No Harm" (*wugonghai*), introduced in 2001, merely certifies that inspected products comply with national standards in terms of environmental quality (including air, water and soil). See Sternfeld (2009) and Paull (2008) for a summary of the development of these systems.

It is difficult to find comprehensive figures regarding the amount of land under different types of cultivation at various times. By 1997 160 "ecological agriculture" pilot sites and 105 demonstration sites had been set up. In 2002 the State Council called for the stepping-up of implementation of the No Harm Food Action Plan, beginning in Beijing, Tianjin, Shanghai and Shenzhen, aiming for the land used to produce vegetables, fruit, tea, fungi, animals and aquaculture products to meet national standards within five years (MOA, 2002). Sun and colleagues (2012) report that in 2006, 23.27 million hectares of farmland were certified to produce "harm free" produce, accounting for 19.1% of total arable land, and that 3.3 million hectares were certified to produce organic food without synthetic fertilizers and pesticides. More recently, ICAMA (2012) gives a figure of 2 million hectares under organic cultivation. Organic cultivation is concentrated in the five Northwestern provinces of Inner Mongolia, Heilongjiang, Jilin and Liaoning, and in Jiangxi, Fujian, Hubei, Shandong and Yunnan. The 12th Five-Year Plan for food safety aims to increase the area used for promotion of "no harm," "green" and "organic" foods to 60%. However, despite more supportive policies, certification for organic food remains expensive, and public trust is low (Sternfeld, 2009).

Other measures have sought to reduce pesticide use in a number of ways, but there appears to be no overall account or assessment of these measures. Sun et al. (2012) indicate that they include trying to separate agricultural extension work from the sale of farm chemicals, and examples of individual programs can be found. For example, as part of its Non-Hazardous Food Action Plan, from 2002 to 2004 the Ministry of Agriculture conducted 400 trainings on "technologies of safe pesticide application" in 60-80 of its 109 appointed non-hazardous vegetable production bases, and some evaluations have shown these to be showing some effect in reducing application rates (Farmer Daily, 2012). There is also more use of Integrated Pest Management (IPM) and pest forecasting systems: one large government-supported project in Yunnan provided insurance to farmers in order to gain support for participation in IPM (Lu, 2010). But it is not clear that these efforts are sustainable after programs end.

4.3 Production process: veterinary drugs

Veterinary drugs administered to animals, fish and poultry for therapeutic, prophylactic or diagnostic purposes, and to promote growth, are of particular concern from a public health perspective because their overuse has the potential to contribute to the genetic selection of bacteria that are resistant to one or multiple antibiotics used to combat disease in human and animal populations. In intensive livestock facilities, entire populations of food animals are often treated when a few animals become ill or to prevent disease during high-risk periods such as weaning or transport. Antibiotics are also fed to entire herds and flocks at low (sub-therapeutic) doses to enhance growth and increase feed efficiency. Heavy use selects for resistant pathogenic bacteria which can also be transferred to other animals in the facility or across farms through manure or more widely during transportation to the slaughter plant. Food products may become contaminated during processing, and raw products can also cross-contaminate other foods during preparation (Marshall & Levy, 2011; Tollefson & Karp, 2004).

This is a relatively new area of regulation at the global level, but concern is mounting. In 2003, the FAO, the World Organization for Animal Health (OIE) and the WHO indicated that "there is clear evidence of adverse human health consequences due to resistant organisms resulting from nonhuman usage of antimicrobials." These consequences include infections that would not have otherwise occurred, increased frequency of treatment failures, increased severity of infections and death (Marshall & Levy, 2011). Regulation of some antibiotics and growth promoters is still in progress. For example, the Codex Alimentarius only recently came out with standards for acceptable levels of the growth promoter Ractopamine, which is used to promote lean muscle growth primarily in pigs and has been approved in 25 countries (WHO, 2012). However, a consensus appears to be emerging that the use of antibiotics for growth promotion and routine prevention should be phased out in order to ensure their continued effectiveness in treating disease (Lancet Infectious Diseases Commission, 2013)

China is the world's largest producer and consumer of antibiotics: in 2007, the estimated annual production was 210 million kg, 46% of which was used in livestock industries (Zhu et al., 2013). Between 1987 and 1999, 283 new veterinary drugs were approved for use. (Chen et al., 2004). No large-scale data are available on the prevalence of ARB in food in China, but a number of small studies provide evidence of their emergence. Broughton and Walker (2009) found antibiotic-resistant strains of salmonella in fish tested in Guangdong markets, and Jiang, Dong, & Zhao (2011) found high levels of resistance to a number of antimicrobials (ranging from 50% to over 99%) in multiple E. coli strains in pigs and poultry, including indications of cross-farm transmission and multi-resistance (81%). Other studies have found ARB in poultry, meat, seafood and milk (Song et al., 2008; Yan et al., 2010; Lei et al., 2010) from different parts of the country, as well as in animal manure, through which they are dispersed into the soil when it is spread as a fertilizer (Zhu et al., 2013).

Although there has been no systematic analysis of the distribution of these problems, it presumably relates fairly directly to trends in the intensification of animal husbandry. Tighter food safety regulations and growing awareness of the long-term global health implications of ARBs will exert pressure to bring their use under stricter control. Importers are also expressing concern (Lauder, 2013). But these efforts will come into conflict with policies that seek to increase output unless regulation and enforcement of antibiotic use improve.

4.4 Food processing: additives

Food safety problems relating to additives involve both misuse of allowed food additives and the use of illegal or non-sanctioned chemicals in food production. Additives are used for a variety of reasons, including increasing aesthetic appeal, extending product life and increasing weight or apparent nutritional content. A number of food safety scandals have involved the use of non-permitted substances in food. In addition to the 2008 milk-melamine scandal, recent cases include the use of illegal additives to make fake "lamb meat" in Liaoning Province and fake "shark fin" in Zhejiang (GAIN, 2013). GFSF lists various examples: pork tainted with clenbuterol; noodles containing ink, industrial dyes and paraffin wax; and sodium borate used to make cheap pork resemble beef (GFSF, 2011).

As with media reporting, research that discusses food additives in China has tended to focus on food crime (Cheng, 2012) or the use of non-sanctioned additives in food production (e.g. GFSF, 2011). A considerable number of studies exist, but cover a limited number of additives and health impacts. Some have focused on the relationship between additives and food poisoning. Xue and Zhang (2013) carried out a meta-review of studies of acute food poisoning sourced from Chinese academic databases for the period 2000-2010, covering 2,387 individual incidents of acute foodborne illnesses. Overall, food additives were responsible for 9.9% of incidents, 3.5% of illnesses and 11.6% of deaths in studies they reviewed. Nitrites were the main type of additive involved. However, the study is limited to food poisoning, understood as "acute or sub-acute foodborne illnesses caused by ingestion of contaminated or toxic foods," with an incubation period of several hours and causing severe symptoms. This very restrictive definition would exclude many illnesses with longer onset periods (melamine poisoning, for example).

As with other food safety problems, available studies do not provide a clear picture of the extent of health problems likely due to additives, and the distribution of risks is also hard to determine. Most likely the major factors affecting exposure to risk are levels of consumption of processed foods, income level and local capacity to regulate food-processing environments. Local dietary patterns will also affect the distribution of risks (as for example the consumption of dairy or wheat products). Media reports of the 2008 melamine incident indicate that victims were predominantly rural and that low cost of the implicated milk powders was a significant factor determining purchasing decisions (Spencer,

2008). This was likely exacerbated by the fact that migrant workers in China, although they live in urban areas for long periods, still retain ties to their place of origin. Their babies are often raised by grandparents in rural areas while parents are away, giving little option but to use milk powder.

The increased use of additives is clearly driven by the increase in consumption of processed food, and to some extent by consumption of food outside the home. Changes in dietary composition will also have an effect. Although studies are patchy and not always methodologically reliable, they do suggest that this is the case. One (Deng et al., 2011) found aluminum—in some cases at very high levels—in several varieties of pre-prepared and processed foods, while another found diets of children in northern China to be very high in aluminum. In both cases, problems are related to high levels of consumption of particular foodstuffs, including puffed rice and puffed wheat products, and wheat-based products more generally in north China (Health News, 2013). The Food Safety Risk Assessment Center has revised policy on various additives containing aluminum as a result (MOH, 2013)

The Chinese system of approval of additives for use in food closely resembles that in other countries. Food additives include "any natural or artificial substance added to food to improve quality, color, flavor, taste of food, and for the purpose of preservation as well processing technologies [used in food preparation]" (MOH, 2013). Policy distinguishes between misuse of permitted additives (*lanyong shipin tianjiaji*) and use of illegal substances (*weifa tianjia feishiyong wuzhi*) in food production. The Ministry of Health produces a positive list of additives that may be used in foods similar to that issued by Codex Alimentarius. The list covers all allowed additives, scope of use and maximum permissible levels. The list is revised periodically; most recently in 2011 and between revisions, the MOH issues updates relating to specific additives which are published on the MOH website. Approval of additives is delegated to the Food Safety Risk Assessment Center (CFSA) (MOH, 2012b). There are concerns, however, that the extent of China's list of additives is limited (GFSF, 2011).

In addition to the role of the MOH and FSRAC in approving additives, in broad terms AQSIQ has responsibility for oversight of production of food additives and use of food additives by food processing companies, SAIC oversees additive quality in commercial venues and the SFDA oversees use of food additives in the F&B industry. The MOA, MOFCOM and MIIT also have responsibility for oversight of different elements of additive use, production or industry oversight.

Since 2009 there have been a number of crackdowns on improper use of food additives, as well as on the use of non-sanctioned additives (MOH, 2009). An MOH notice from 2011 states that in 2010, 97,000 additive producers and 3.6 million food production companies were investigated, resulting in the discovery of 5,305 infractions.[9] For the most part, these were dealt with through fines, though 36 cases were referred to the legal system and

23 arrests were made (MOH, 2011a). GFSF reports a similar campaign in 2011, resulting in more than 2,000 arrests and the closing of 5,000 businesses (GFSF, 2011, p. 16). Small companies and restaurants, as well as milk selling, transport and sale of live poultry and slaughterhouses, are considered to be weak links, and/or require greater oversight (Office of the State Council, 2011). In addition, recent provisions exist aiming at strengthening use of legal punishment of those found to be using illegal additives.

As well as short-term crackdowns, policy operates on various levels, including increasing governance of companies producing food additives (including registration, oversight, required standards, etc.), labeling of foods containing additives and mandating record-keeping on the part of food processing companies, as well as "trust measures" (company dossiers and the like), and promoting increased management and education by industry and industry associations with the aim of ensuring processing companies use only sanctioned additives from accredited producers (Office of the State Council, 2011).

In the last few years, the MOH has released blacklists of banned and easily misused substances to help guide sub-national governments in their oversight and enforcement work. In 2011, the MOH released a synthesized list of such substances comprising 47 illegal substances and 22 misused additives (MOH, 2011b). Sub-national governments are required to report any such substances they discover during oversight work to the national government (SFDA, 2011) to be included in reference lists for circulation to other areas and inclusion in food safety risk assessment plans formulated by provinces (MOH, 2011c).

The MOH recognizes that local-level capacity to test for food additives is in urgent need of strengthening (*jiada jiaqiang*) in terms of equipment, personnel training, etc. There are plans to strengthen this in the 12th Five-Year Plan period (MOH, 2011d).

9.As far as is ascertainable from the relevant policy, "food production companies" refers to companies involved in the processing and production of foodstuffs, excluding both primary production and food and beverage industries (see MOH, 2010). Given apparent lack of clarity over the definition, it is hard to know how this relates to figures cited for numbers of food processing companies.

5. POLICY AND GOVERNANCE CHALLENGES

Food safety policy includes measures relating to the oversight of food production and testing of foodstuffs that are specifically conceived of as "food safety policy" and introduced by agencies under this rubric. In many ways these measures are similar to those that aim to regulate other policy domains such as construction and manufacturing, and they present similar challenges in terms of the need to quickly scale up capacity for enforcement.

At the same time, many other government policies affect food safety but are not necessarily explicitly framed in these terms. This includes policies relating to industry and supply chain development, industry upgrading, land zoning and protection or improvement of agricultural environments. While hard to delineate as a coherent policy domain, an expanded definition is more meaningful in terms of understanding the drivers and likely trends in food policy, as well as possible levers of intervention.

5.1 Limited oversight and unclear responsibility

Numerous analyses have pointed to the fragmentation of oversight of various components of China's food supply chains and the absence of a clear "farm-to-fork" remit of any one department or agency. In early 2013, a National Food and Drug Administration with full ministerial status was established, in accordance with the "State Council Institutional Reform and Transformation of Government Functions" approved at the first session of the 12th National People's Congress (NPC), and the State Council Notification on Organizational Arrangements (2013:14). Prior to this, thirteen central government departments had some kind of responsibility for various aspects of the supply chain from production through distribution to sale, with a State Council working group charged with coordination of the work of different ministries (Zhang, 2013). This fragmentation of responsibility resulted in overlaps and gaps in both government responsibility and in policy.

Equally, there are areas of indeterminate responsibility. Laws are found to be insufficiently precise and to suffer from poor coordination. Multiple and conflicting standards exist, as do multiple permits and standards for market entry, leading to inefficient use of government resources and low efficiency of oversight. Poor coordination between mandates of different ministries at the implementation level is also a concern (see also GFSF, 2011, p. 28). There seems to have been little systematic analysis of how these factors play out across industries, but one analysis points out that prior to the recent reform, oversight of slaughterhouses for pork fell under a different ministry than that overseeing slaughterhouses for beef and poultry (GFSF, 2011, p. 25). And another study found that the results of CDC surveillance for bacterial pathogens and antibiotic resistance were not linked

to agencies responsible for enforcement of food safety regulations, but sent to the central government' s CDC (Broughton & Walker, 2010).

The most significant problems associated with the previous institutional arrangement of China' s food safety governance system have been addressed in the State Council's organization reform. The plan established a China Food and Drug Administration (CFDA) which will integrate the responsibilities formerly held by the Food Safety Office and the State Food and Drug, Administration (SFDA) as well as the responsibilities of the Quality Inspection Agency for the production environment and of the Commerce Ministry for distribution. The CFDA will have the responsibility of ensuring the effective regulation and management of food and drug safety at every stage from production through distribution to sale. In order to ensure integrated management and clarify responsibility, the new agency will be responsible for assessing food safety risks and setting food safety standards. The Ministry of Agriculture will be responsible for the regulation and management of food safety relating to agricultural products and will take over responsibility for the regulation of slaughtering of pigs from the Commerce Ministry. The explanation of the plan states that after reform, agencies involved in food safety management should "change their ideas towards management, use innovative methods and make full use of market mechanisms, industry self-regulation and oversight by society."

This reform is to be implemented from the national to the county level by the end of 2013. As a new measure, its effectiveness is as yet unclear, and will probably depend in large part on whether adequate resources and capacity building are provided at all levels. Diagram 1 reflects the changes in the governance of food safety resulting from the State Council institutional reforms in 2013.

Diagram 1: Establishing the China Food and Drug Administration (CFDA)

*CFDA will perform its functions
**No longer exists

Adapted from Chongqing Daily, 2013.

5.2 Limited and uneven implementation capacity

A number of problems have been identified in the implementation of food safety policy to date, including a shortage of professional implementation staff to deal with large, complicated and fragmented industries, as well as a lack of equipment for testing and analyzing food. The role, and capacity, of central government in actual oversight is limited, and most hands-on management, including inspection, takes place at sub-national levels where capacity is insufficient. The SFDA was under-resourced: food and beverage industry monitoring personnel should have been 50,000, but in fact only 10,000 personnel were in place in 2012 (Zhang, 2013). According to GFSF (2011), only seventy vocational colleges in China carry out training in food testing and related fields, and most of these are only newly established; training is likely relatively poor and insufficiently practical (see also GFSF, 2011, pp. 54-55). Considerable differences in capacity and staffing exist between urban and rural areas (Liu, 2010).

Little research on facilities for food safety testing exists. One 2008 study reported that there were 3,913 food testing laboratories accredited by the China National Accreditation Service for Conformity Assessment, including 48 state-level and 35 key national laboratories under AQSIQ (Ellis & Turner, 2008, p. 35). More recent research reports more than 6,000 laboratories, and staffing numbers of around 60,000 (Jia & Jukes, 2013). Current policy envisages development of a three-tier laboratory system, with responsibilities defined by level of laboratory (State Council, 2011). Meanwhile, equipment, especially for rapid testing, may also be inadequate or available only to better-resourced areas. The Beijing government has recently invested in compact, networked rapid testing equipment (FPD, 2012). It is unlikely that many localities can afford such equipment, and national policy calls for priority domestic development of rapid testing technology (Office of the State Council, 2012a). Food destined for the domestic market appears to be tested much less than that destined for export markets. Testing is also often partial and/or inadequate, and may be almost completely absent at the farm gate (Ma, 2012).

Inconsistencies in the object of regulation exist: in some cases, policy may only apply to farms or producers above a certain size. China's 12th Five-Year Plan on prevention of pollution from livestock and poultry raising (2012), for example, applies only to farms above a certain size, and this depends on the animal raised. In the case of pigs, farms above the stipulated size account for only 5.4% of farms, and this number is even lower in the case of chickens. Large farms tend already to have control procedures, while small farms fall outside the scope of regulation and lack the resources to implement these procedures anyway (Zhang, 2013): GFSF claims that over half the pork consumed in China goes through slaughterhouses that are not subject to inspection (GFSF, 2011, p. 28), although the actual food safety hazard associated with this is unclear.

The degree to which produce is tested in wholesale or wet markets is unclear. It is likely that oversight of wet markets and testing of market produce is locally variable. Some cities

have implemented consolidation policies, putting urban wet markets under professional management or banning outdoor markets (Reardon, Timmer, & Minten, 2012), though it is not clear how successful these efforts are. Broughton and Walker (2010) report random testing of aquaculture products for chemical residues in wholesale markets in South China, but that results of tests appear not to be shared with any government department, and that it is unclear whether any action is taken in cases where foods test positive for banned substances. Much policy remains "campaign-style" and revolves around periodic clamp-downs on unlicensed traders, small processing factories and other elements deemed undesirable. Inevitably, the effectiveness of this is only short-lived (Zhang, 2013). This approach has been evident in following the 2009 Food Safety Law (Office of the State Council, 2012b; Office of the State Council, 2012c).

Revision of the Food Safety Law has been seen as one way of dealing with these problems. In May 2013, the State Council decided to include revision of the Food Safety Law in the legislative agenda for 2013. In June, the Legislative Affairs Office of the CFDA issued a notice soliciting opinions from society, and in July, the State Council issued the "Decision on Strengthening Food Safety Work" which presented a series of stages for strengthening food safety management. From the 29th of October to the 29th of November 2013, the Legislative Affairs Office of the State Council solicited opinions on the draft of the revised Food Safety Law. This covers several dimensions including implementing reform of institutions and government agency functions, increasing responsibility of enterprises and local government, innovation in regulatory methods, improving social oversight, and stiffer penalties for those who violate the law.

Although the law calls for strengthening social oversight, Clause 106 states that "any organization or individual that publishes information regarding food safety that may have a serious impact on society or on an industry, must first confirm the [the accuracy of] the information with enterprise concerned, the relevant industry association, research organizations [and/or] the food and drug safety administration… no organization or individual will publish uncorroborated information regarding food safety or generate or circulate false information." This clause has received critical comments from legal experts and social organizations, who argue that it will weaken capacity for public oversight and have recommended that it be deleted.

5.3 Modernizing food supply chains: vertical integration

In addition to food safety policies that are directly framed as such, another set of measures are in operation that seek to address what many analysts see as the fundamental problem of the "fragmented (*san*), small-scale (*xiao*) and weak (*ruo*)" nature of China's agricultural structures (Waldron et al., 2010). These policies aim to modernize agricultural production and supply chains through the vertical integration, at least in part as a means to increase

safety of agricultural products (Zhang & Aramyan, 2009; Gale & Hu, 2012). There have also been attempts to increase horizontal coordination of producers through producers associations and cooperatives as a route to standardizing production and increasing traceability.

Various forms of coordination and consolidation strategies exist. In the crop sector, in addition to development of rental markets for land as a means of allowing a degree of consolidation of farmland, other significant institutional means of consolidation include development of so-called "dragon-head enterprises" and of cooperatives. Dragon-head enterprises are scale producers supported by government as a means of encouraging vertical integration. The range of functions that may be served by such companies includes providing inputs, technical advice and processing functions, as well as linking farmers to markets. Development of dragon-head enterprises is ongoing, and policy support has been reiterated in the 2013 Number One Document. Typically, dragon-head enterprises engage in various forms of contract farming, including direct contracting with households, combined with setting-up of production bases in nearby areas, and forms of contracting employing intermediaries between households and companies (Zhang, 2012, cited in Keeley, 2013). A second significant form is the promotion of agricultural cooperatives, development of which has benefited significantly from recent policy support, especially the 2006 Rural Professional Cooperative Law. These two modes of de facto consolidation are not mutually exclusive: companies may sign production contracts with cooperatives, for example.

Forms of consolidation are complex and there has been no systematic analysis of the way in which they operate across product sectors. Keeley (2013) details a range of measures for supporting scale in pig-rearing, including grants for facilities, veterinary services, etc., to scale producers, as well as tax waivers for large-scale producers. There is also policy support for the introduction of specific breeds, and the MOA supports coordination between feed producers, meat producers and processors. Consolidation is underway in other sectors, most obviously dairy in the post-2008 period (for more details see Keeley, 2013).

Vertical coordination is often discussed in terms of ways of "linking" companies and farmers (Gale & Hu, 2012). One example employed under the 11th Five-Year Plan involves development of modern slaughterhouses capable of producing in line with safety standards. This is intended to promote forms of vertical contracting with dedicated suppliers, thereby increasing the technical capacity and quality standards of small farms (Waldron et al., 2006). However, according to Gale and Hu, this strategy has not been entirely successful. In the pork industry for example, control of the supply of pigs is only partial as slaughterhouse capacity frequently exceeds local production capacity, requiring companies to source pigs on the open market which may have been given feed containing banned additives (Gale & Hu, 2012). Similarly, although the beef industry is growing rapidly,

the limited market for premium meat compared to the capacity of modern abattoirs means that most are forced to operate under capacity, placing them under high commercial pressure. Research has found that this can result in illegal measures to increase profitability, such as infusing fat into muscle in order to mimic marbled beef and injecting water to increase weight (Waldron et al., 2010).

In vegetable production, various strategies exist for linking companies and farmers: direct management of consolidated parcels of land, as well as various forms of contracting with farmers and/or intermediate organizations (cooperatives, etc.) for produce. Direct management relies on contracting with villages to consolidate land holdings, which can then be directly farmed and managed by agricultural businesses with the advantage of allowing direct oversight of production techniques, inputs, etc. Other methods include contracting with small farmers who supply labor and carry out actual farming using specified inputs (Calvin, Gale, Hu, & Lohmar, 2006; Stringer, Sang, & Croppenstedt, 2009; see also Hu, Reardon, Rozelle, Timmer, & Wang, 2004). Parallel efforts have been made in modernizing wet markets through zoning, outlawing open air markets, improvement of market premises and improving management via bringing in external managers or auctioning wet markets to supermarket chains or agricultural businesses (Reardon & Gulati, 2008). Other programs aim to increase supermarket chains' sourcing directly from farm cooperatives and distribution centers in production areas (Gale & Hu, 2012), on the principle that this direct interaction will increase standards through controlling of inputs, testing of produce, etc.

Overall, strategies for increasing vertical coordination rely on the ability of downstream actors to enforce production standards among farmers and upstream producers, an important indicator of which is the existence of long-term relationships and contracts in supply chains. There have been no systematic studies of the penetration of modern supply chains into rural areas (Wang et al., 2009), but available evidence suggests that it is very limited, resulting in very little testing of produce and almost zero provision of extension services by buyers (Huang, Wu, Zhi, & Rozelle, 2008). Mid-2000s research on vegetable supply chains in Beijing and Shandong, two of China's most developed horticultural markets, shows very little use of supply contracts, with only an estimated 4% of vegetables supplied to the Beijing area going through "modern" supply channels (supermarkets, professional suppliers or processing firms), with the majority of produce continuing to be sold by small traders operating in agricultural produce wholesale markets. This research shows little use of long-term contracts, with implications for the degree to which purchasers provide extension services, control inputs and growing conditions, etc.

The same study found that in the Beijing area supermarkets source around two-thirds of horticultural produce from wholesale markets. The main reason appears to be the extreme competitiveness of wholesale markets dominated by small-scale aggregators and traders with very low overheads who are able to source at very low cost, meaning

that supermarkets must rely on wholesale markets if they are to remain competitive. Other studies (Huang et al., 2006) have also found little use of contracts, little testing for pesticide residues, as well as little use of extension services in production, with sales almost exclusively conducted on spot markets. These studies suggest that traceability is extremely hard under such conditions and that vertical integration is proving difficult. Small-scale surveys of pesticide residues on supermarket produce in several large Chinese cities carried out by Greenpeace, show noticeable differences in performance of different supermarkets (Greenpeace, 2011). All though the sample is too small to generalize, this suggests that differences in supply change management may be having an effect.

Although various "models" of supply chain management have been identified (e.g. Hu, 2011), there appears to be little detailed analysis of such strategies, their effectiveness and possible wider applicability. Research on these issues also remains confined to large and developed cities; there appears to be a dearth of information on the extent to which modern supply chains in smaller cities and rural areas can increase food quality and safety.

Other forms of supply chain integration are underway, with the aim of developing "short food supply chains," and shrinking the distance between producers and consumers, increasing interaction and improving quality. Many such initiatives are recent and no comprehensive data exist on their extent or efficacy in ensuring safe food supplies, Zhang (2013) divides these into several main types: increasing agricultural production in urban areas; forms of community-supported agriculture; forms of direct selling between producers and consumers, whether face-to-face or internet-based; various forms of third-party guaranteed systems, including third party authentication systems; dedicated retail formats (organic, etc.); and creative solutions using trucks contracted to source directly from producers and directly supply periodic small-scale markets operated in car parks and other available spaces in urban residential compounds. In addition, many "linking" policies exist, including farm-restaurant linkages and farm-school (college, university, etc.) linkages. These linking policies are variants on farm-supermarket linking policies described above. Farmers' markets, in which producers sell directly to final consumers, exist in some cities in China, but are likely more common in more developed regions.

The types and scales of initiatives described here are increasing, and media reporting of these exists. To date, however, there is little evaluation of their effectiveness (Zhang, 2013). Indeed, the proliferation of different forms of implementation under large-scale national policies such as the farmer-supermarket linking program—different supermarket chains may operate different models, for example (Hu et al., 2004; Hu, 2011)—is likely to make any overall evaluation hard. Much of the data reported here were collected in the mid-2000s, and it is hard to know whether findings of studies cited here remain valid. There appear to be no more recent supply chain integration studies (see Huang et al., 2012).

5.4 Modernizing the food system: horizontal coordination

Horizontal coordination is another potential strategy for overcoming problems associated with "fragmented, small-scale and weak" agricultural structures. Analysis to date has focused on the development of cooperatives, and their potential to ensure production of safer food. The extent of cooperatives has increased substantially, to around 20% of villages by 2008, or around 9.5–10% of rural households (CCAP and MOH figures cited in Huang et al., 2012, p. 28). Analysis by the CCAP finds that most cooperatives provide services related to production technologies and marketing to their members, with almost half (49%) arranging for purchase of agricultural inputs, principally fertilizers and animal feeds, and sometimes pesticides and seeds.

It is unclear, however, how much cooperatives contribute to ensuring food safety. Jin & Zhou (2011) argue that standardizing production practices in small-scale farms is hard because many small farmers cannot afford the costs of compliance with national standards programs (no harm, green and organic) and their level of education is low, meaning that many do not fully understand the benefits of adopting standards. Research in Zhejiang has found that the adoption of national food safety and quality standards was associated with cooperative size, perception of standards, reputation, expected costs and benefits and destination market. (Jin & Zhou, 2011). A cross-regional survey of 157 cooperatives found that only 18% of cooperatives reported that buyers mandated food safety standards, and even fewer actually supervised production (11%) or rejected produce when substandard (17%). More encouragingly, though, surveyed cooperatives reported much stricter requirements relating to all the above (54%, 67% and 48%, respectively) from buyers in modern supply chains (supermarkets, processing firms, restaurants or other professional suppliers) compared to traditional (wet markets) and wholesale channels (Jia, Huang, & Xu, 2012). It is therefore likely that a continuum exists, and that where modern supply chains and increased organization through cooperatives intersect there is potential for higher standards, including around food safety.

Overall, analysis of strategies of vertical integration and horizontal coordination of food production and supply chains that are being introduced as part of efforts to modernize China's agricultural structures has not yet found very positive impacts in terms of food safety (see Gale & Hu, 2012). That said, significant efforts are underway (see Keeley, 2013), and one can expect that over time these will have an impact on standards and food safety. However, much of the literature is based on data that are now old; evaluations are patchy and show a range of outcomes and new forms of coordination are emerging. More systematic analysis is needed of the way in which these strategies play out in different jurisdictions and industries, and of the interaction between horizontal and vertical coordination strategies.

5.5 Governance challenges

Certain challenges to governance of food safety stand out in much analysis: challenges related to the nature of industry structures and dynamics and managing rapid change; challenges of policy implementation resulting from uneven development and center-local relations; and challenges of over-reliance on government as an agent of change where civil society, courts and media are weak.

5.5.1 Industry structures, dynamics and rapidity of change

Many food safety problems are related to the rapid expansion of industries and markets, price volatility and highly competitive markets. A number of recent incidents illuminate this. For example, in the case of the milk-melamine scandal of 2007-2008, extreme competition in the early 2000s pushed down milk retail prices which, combined with rising prices of production inputs (mainly feed), ultimately pushed many farmers to cull cows in 2005 and 2006. This, in turn, led to a "scramble for milk" in 2007, as companies competed to buy limited supplies of milk from reduced herds. High demand, limited supply and soaring prices of both milk and feed seem to have created "a strong incentive to water down milk or to accept substandard milk at a time when adulteration [with melamine to disguise low protein levels] was apparently increasing" (Gale & Hu, 2009; see also Mo et al., 2012). In this market, both producers and processors had little bargaining power, and all players in the milk supply chain, from small farmers and milk stations to large processing companies, had an incentive to reduce costs or increase value of sales. Large milk processors "habitually" purchased sub-standard milk at reduced prices and, as well as allowing their own farms to add water to milk, informally sanctioned the addition of melamine. (Xiu & Klein, 2010).

A similar picture emerges from analysis of the meat industry, with rapid expansion and tight competition combining to generate incentives for illegal practices. Li (2009) argues that rapid, government-promoted expansion of the meat industry and an emphasis on quantity over quality have had consequences for animal welfare and for food safety, including recycling of diseased carcasses into the food chain, excess use of antibiotics and use of banned growth-promoting chemicals and lean meat powders (*shouroujing*). Some of these impacts are complex and unpredictable. Brown et al. argue that the building of modern abattoirs in order to centralize slaughtering and increase inspection of carcasses can speed up the distribution of wet beef to consumers and reduce risks through greater inspection, cleaner facilities and more timely distribution. But where centralizing slaughterhouses increases time between slaughter and consumption, the strategy may be counter-productive, possibly increasing risk (Brown et al., 2002).

In case studies of particular food safety problems, a number of factors repeatedly emerge: changing industry structures, rapidity of market development, rapidly changing prices of both products and inputs, competitive markets and low profit margins, weakness and lack

of bargaining power of key players, and inability of government to regulate competition and bring order to markets in real time. Analysis points clearly to the need to understand policy in context and to understand food safety in the context of changing industry structures and development, geography and the interests and strategies of multiple actors (both state and non-state) in complex environments. This is not restricted to identifying needs for regulation and testing, but also encompasses government support and guidance for development of specific products or industries, as well as overall macro-economic regulation, price and market management (see Norse et al., 2012, on pork markets; Gale & Hu, 2009, on the dairy sector).

5.5.2 Central-local relations and limited governance toolbox

Many analyses present food safety problems as a simple question of policy implementation, arguing that sub-national governments lack capacity and implement national policy poorly. But the problem of weak implementation, which also affects many other policy areas, stems to a great extent from the interaction between central control over the policy agenda with the very uneven distribution of resources between the central and local state in China.

Changes to China's fiscal regime since the 1980s have transformed what was previously a "province-collecting, center-spending fiscal regime" into one in which sub-provincial levels must be largely fiscally self-reliant (Saich, 2011). This has led to great economic dynamism, but also to large disparities across sub-national jurisdictions which the fiscal transfer system fails to offset (Wong, 2009). Local governments, often at the county level, are required to implement much central policy, but funds to meet central mandates must frequently be found locally and differences in local resources have therefore led to large imbalances in implementation capacity and service provisioning. Local governments are also highly dependent on local industry for tax revenue, making it difficult for them to close down or impose high costs on polluting or unsafe operations. In the case of food safety, this means that local governments frequently have little capacity to implement regulations handed down from the province or center, and simultaneously face contradictory pressures, on the one hand to enforce standards and on the other to avoid closing businesses which provide employment locally (see Ellis & Turner, 2008). This is not helped by the fact that much management of food safety is concentrated in relatively "weak" government departments, such as the health system.

But local governments also differ in wealth, capacity levels and the challenges they face. In general, rural areas have lower capacity than urban areas, but both rural and urban spaces exist along a continuum from poor and low-capacity to relatively rich and high-capacity. Equally clearly, sub-national governments have a degree of space to develop local policy solutions. For example, Shanghai seems to be in the vanguard of sub-national Chinese jurisdictions in terms of food safety management, and the challenges it faces resemble

those of a developed country importer. Since the mid-2000s Shanghai has developed a distinctive model of oversight and policing of "imports" (Shanghai Municipal Food and Drug Safety Research Center, 2008). More broadly, sub-national governments may well carry out proactive regulation (see full report for examples).

But Shanghai is an extremely high-capacity and wealthy city, and policy solutions it arrives at will not necessarily be applicable elsewhere. Uneven development means that a "one size fits all" view of Chinese food safety problems and solutions is unachievable. In many cases, constrained local revenues will mean a much more limited government response. To a certain extent, though not entirely, increasing government capacity to ensure food safety is therefore a developmental question, not just a question of poor policy implementation. Improvement will inevitably take time and be uneven, and it will depend to a large extent on fostering capacity at the county and even township level (Office of the State Council, 2012b). Much current policy stresses the need for coordination and management of food safety work by sub-national governments, and specifies that food safety will be included in the assessment criteria (*kaohe*) of local governments. However, the appropriate resources and human resource development will need to be allocated to make this a reality.

Government aside, China has a comparatively limited governance toolbox for dealing with food safety compared to more developed economies; research points to the lack of a strong legal system, insurance companies, industry associations and "consumer watchdogs" to support and supplement government efforts to ensure the safe production and processing of food (Thompson & Hu, 2007, p. 6). The extent to which the legal system is playing a role in enforcing food safety in China is unclear, and there appear to be no studies of the role of either consumer or industry groups in relation to food safety in China.

5.6 Policy directions

The Food Safety Law (2009) is frequently cited as a major turning point in China's management of food safety. Broadly, this should be seen as part of an ongoing process of development of a "new regime of regulatory governance" suited to a market economy. Such analyses point to an increasing degree of consolidation of responsibility in a smaller number of government departments, and an increase in the use of coordination mechanisms to bring together departmental interests and work, as well as the reframing of policy in terms of "food safety" rather than the more limited concept of "hygiene" (Liu, 2010).

The Food Safety Law and subsequent policy is of very broad scope. Several major areas of work in the law include: development of surveillance systems and assessment of food safety risks; large-scale consolidation of food safety standards; changes to regulation of production and trade of foodstuffs, including encouragement for scale production and development of recall systems; food testing. The Law, as well as the more recent (2013)

government reshuffle, increases coordination of food safety management in order to overcome regulatory fragmentation.

Several areas of particular note given discussions above include the large-scale consolidation of standards for food safety, the development of systems for risk-based evaluation of food safety and plans for the extension of responsibility for food safety to ever-lower levels of government, including the township level (Office of the State Council, 2012b). Building capacity for effective monitoring and oversight at such low levels of government will be challenging. Costs relating to personnel, administration, sampling and inspection of products, as well as information dissemination and education are to be borne by governments from the county level upwards (Office of the State Council, 2012b). Levels of funding available will differ locally, and building capacity will likely take time. In addition, food safety is to be included as an indicator in evaluation of sub-national governments (Office of the State Council, 2012b, Article 28), and at least some sub-national governments are already putting this into practice (Guangzhou Daily, 2013), which has the potential to substantially increase local government attention to food safety management.

No detailed or comprehensive analysis has been conducted of the multiple policies and initiatives being implemented across government agencies and the multiple emerging sub-national initiatives. Documenting and evaluating these will be an important priority for research. Nonetheless, the scope and ambition of current reform efforts is clear.

6. BEYOND GOVERNMENT

6.1 The role of media

The media plays an important role as a source of information about food safety for both the public and the government. New media, in particular microblogs (*weibo*), have also become a space for citizens to air their opinions and grievances about food safety problems, serving to some extent as a barometer of public opinion (Yang, 2013). Although empirical research is scarce, a few observations can be made about media reporting on food safety.

First, as in other countries, the imperative for a good story leads to a bias in reporting, which tends to favor issues that involve acute health problems like food poisoning or dread diseases like cancer, as well as those affecting populations that elicit special sympathy such as children. Slower-burning problems or those with chronic or more indirect effects, like the misuse of veterinary drugs, appear to receive less attention even though they may be much more serious from the point of view of public health. In this sense, the melamine crisis presented a perfect story, involving deliberate fraud that led to the poisoning of children. However, as Yang's (2013) analysis of the evolution of reporting on this issue shows, political factors also come into play in determining what gets reported and how, particularly questions regarding attribution of responsibility for food safety problems and the way in which they relate to broader political issues of corruption and official malfeasance. In the case of the melamine scandal, the story became too sensitive and was pushed out of the mainstream press into the sphere of microblogs.

Availability of information is another factor that affects reporting. In the absence of comprehensive, publicly accessible data, the media report on food safety issues that are brought to their attention, sometimes by researchers, but more often by advocacy NGOs or the direct victims of food safety problems. This means that reporting often lacks context about the prevalence and severity of different risks, and this probably contributes not only to spiraling public anxiety but also to a disproportionate concern about some issues over others. To the extent that the media is also a source of information for government, this may also affect policy and enforcement.

Given the complexity of many environmental effects on health and the numerous interacting policy and market incentives involved, it is also not surprising that many media accounts fall back on more straightforward narratives of declining moral standards, or corporate or government corruption, especially when the latter are clearly an issue in some cases. However, reflecting the public demand for more detailed and reliable information,

at least one program is now beginning that will involve scientists writing columns on food safety issues (several already have well-subscribed blogs) (Chen Nengchang, personal communication).

The relationship between media and corporations as it relates to food safety is a question that has received little attention. Media reporting clearly shapes consumer confidence in products and brands reported to have problems with food safety. In the wake of the 2008 melamine scandal, sales of dairy products declined dramatically (Halliday, 2008; Wiggins, 2008). More recently, Yum! Brands (the parent company of KFC) was discovered to have sourced chickens from suppliers using excessive levels of antibiotics. The company was investigated by food safety agencies following a report by CCTV, and the discovery prompted a news and internet backlash that resulted in very dramatic declines in sales and the company's share price (New York Times, 2013). Incidents such as this point to the potential for consumer sway in increasing pressure for food safety where sufficient transparency exists and companies have brand integrity or share price to protect.

6.2 Public perceptions and responses to food safety concerns

Most of this report has dealt with assessments of food safety risks conducted by scientific researchers. But public perceptions of risk are also important in driving demand for government intervention and for products that are regarded as safe, including imported products and "no harm," "green" and "organic."

Public debate about food safety in China is characterized by a sense of extreme anxiety and uncertainty. Surveys have found that the public regards food safety as the second greatest risk in daily life, with 92% expecting to be the victim of food poisoning in the next year (cited in Lancet, 2012). A joke being circulated on SinaWeibo[10] conveys the general public concern: "If you eat animal meat, you worry about hormones. If you eat vegetables, you worry about poisonous chemicals. If you drink soda, you worry about pigments. It's hard to tell what is eatable" (Yang, 2013).

On the one hand, the public seems to feel bombarded by risks of equal severity, and this reflects the lack of reliable information about the actual level of risk from different sources. However, the limited research that has been conducted on perceptions of food safety risks shows that the focus of public concern has also shifted over time and reflects the media focus on scandals. A survey of 570 supermarket consumers in Nanjing conducted in July 2003 found that respondents were most concerned with the expiration date of products, pesticides and other chemical residues and with preservatives, pigments, and other additives. But by 2010 when Yang Guobin analyzed tweets relating to food safety posted on SinaWeibo, he found that tainted milk powder was by far the most important issue. Other issues mentioned also reflected media attention to particular problems, including

10.A "microblog" service, similar to Twitter.

bottled water, sewer oil (*digouyou*) used in cooking, eggs (with Sudan dyes), salt with potassium ferrocyanide, hotpot lamb and a number of other foodstuffs. The majority of concerns involved additive or fake products, and problems were attributed to greed among businesses and government shirking responsibility or being corrupt (Yang, 2013).

Attitudes and knowledge about food safety problems vary by income, educational level and other demographic factors (Ipsos, 2012), and studies have found that younger and better-educated consumers are more likely to pay for traceability (Zhang, Bai, & Wahl, 2012). However, little is known about how risks are ranked by consumers, or how perceptions of what foods are most likely to be prone to safety problems affect willingness to spend scarce resources; for example on certified milk or on traceable vegetables. Nor is it clear how purchasing decisions link to lay "risk mitigation" strategies such as precautionary soaking of leafy vegetables and excessive peeling of root vegetables and fruit to remove possible contaminants. Anthropological studies of consumer attitudes to food safety have potential to throw light on such issues but are quite limited to date (for a review of recent studies see Xu, 2013, p. 2) and the work of Klein (2013) suggests that concerns about food safety are intertwined with those of taste, freshness and local origin.

An important question is how consumer perceptions of the relative risk associated with specific food types, and the spending priorities and countermeasures they engage in, would compare to an evidence-based evaluation of risk across product categories and the implications of this for risk communication about food safety. Mostly likely, perceptions, priorities and counter-measures all vary to some extent by place, demographic group and other factors, but to date most studies of consumer attitudes are based on urban populations sampled in a limited range of venues.

In a context where public trust in institutionalized mechanisms for ensuring food safety has yet to be established, the last few years have seen the rapid growth of interest in alternatives to traditional food supply chains. These mostly represent efforts on the part of urban consumers to establish direct relationships with farmers in order to ensure access to safe and high quality food through community supported agriculture, urban gardening, farm-community linkages and collective purchasing (Zhang, 2012; Shi et al., 2011). Although these programs affect a relatively small number of people, when successful they can provide healthy food to urban consumers, promote environmentally friendly production and support farmer's livelihoods. Research could usefully investigate the efficacy of different models and the possible room for expansion.

6.3 Consumer willingness and ability to pay

Consumer willingness or ability to pay a premium for food products with demonstrable "food safety" characteristics is a factor in the feasibility of increasing monitoring and testing in food supply chains, as well as in the upgrading of food supply chains more generally. There is evidence, for example, that increased inspection and testing following the 2009 Food Safety Law is leading to a rise in prices due to increased costs of compliance, though it is unclear by how much (USITC, 2011, pp. 5-18). Analyses of costs of complying with standards such as HACCP find these to be high but bearable for larger processing companies and/or exporters, but caution that compliance may well be out of reach for smaller companies supplying domestic markets on thinner profit margins (Wang et al., 2009; Wang, Weng, Yutaka, Fukuda, & Kai, 2007). Equally, understanding willingness to pay (WTP) for quality/premium products and what the market will bear is "crucial for policymakers and firms to conduct cost and benefit analysis before launching any food traceability related policy or starting any consumer campaign programs for the policy" (Zhang, Bai, & Wahl, 2012). Research on beef supply chains by Waldron et al. (2010), for example, shows that the official strategy of industry-upgrading founders on the absence of a sufficiently strong consumer demand for high-end beef.

Currently, evidence regarding consumer willingness to pay is partial and contradictory. Most surveys conclude that Chinese consumers are willing to pay a premium for product attributes indicating quality, principally some form of labeling/certification (Xu, Zeng, Fong, Long, & Liu, 2012; Wang, Mao, & Gale, 2008; Ortega, Wang, Olynuk, Wu, & Bai, 2012; Ellis & Turner, 2008) or assurance of traceability (Zhang et al., 2012). However, surveys address different populations at different times, use different methods and enquire about different products, limiting comparability and producing different rankings of the food safety attributes that are important to consumers, including official certification, private certification, brand, purchase venue, etc. (e.g. Ortega et al., 2012; Zhang, Bai, Lohmar, & Huang, 2010). In general, research indicating that WTP for traceable and organic food is higher among young people (Zhang, Bai, & Wahl, 2012) suggests that WTP will likely increase over time and probably become more general than is demonstrable from current studies. However, it is quite possible that existing studies overestimate WTP because they tend to focus on urban consumers (e.g. Zhang, Bai, & Wahl, 2012) and on supermarket shopping (e.g. Xu et al., 2012). Little targeted research has been done on rural populations or second- and third-tier cities, or on more "traditional" sales venues such as wet markets.

Furthermore, while WTP may be flexible among higher income groups, for poor people it runs into the hard constraint of capacity to pay. For example, one consumer strategy has been to switch to consumption of imported products based on the belief that these are likely safer than domestically-produced ones. This has been particularly obvious in the case of milk powder and baby formula (Jacob, 2013). A recent Ipsos survey found that more than 60% of respondents in seven large Chinese cities intended to increase consumption of

foreign brands, and that 28% would increase their purchases of imported foods/brands as a result of food safety scares (Ipsos, 2012). However, many consumers do not have this opt-out strategy.

More generally, the Chinese government is very aware of the importance of food price inflation for broad swathes of the Chinese population (Wen, 2011; Han 2007) and a balance will need to be found between this concern and the costs involved in improving food safety. In terms of general policy, ensuring the widespread implementation of low-level and less-expensive certification schemes, such as "no harm" schemes, may be appropriate for the levels of purchasing power of a developing economy at least as a transitional measure (Paull, 2008). But even this will take time and is likely to proceed unevenly.

Meanwhile, although exposure to food safety risks does not always correlate neatly with socioeconomic status, when it comes to selective purchasing the wealthy are privileged consumers and this has social justice implications. In designing local-level initiatives to reduce exposure to particular food safety risks, it will be important to consider how these relate to capacity to pay and how risks to low-income or other vulnerable populations might be reduced, for example through public education regarding the risks from additives in cheap processed foods, or in extreme cases, by providing alternative supplies when staple products like rice or vegetables are seriously affected.

7. CONCLUSIONS AND RECOMMENDATIONS FOR RESEARCH

China's food system has undergone profound changes over the last 35 years in the context of rapid urbanization and industrialization. In broad terms this has involved a huge increase in agricultural output and in the range of foods produced, an increase in the average scale of production (although still in the context of fragmented landholdings and food-related enterprises), and lengthening of supply chains. Rising incomes and urbanization have meant an increase in the consumption of meat and dairy products, of processed foods and of food consumed outside the home. These changes, as well as the interaction of food production with other drivers of China's rapid economic growth—in particular industry and mining—have produced a range of new food-safety problems related to heavy metal contamination, farm chemicals and veterinary drugs, and additives. Although food safety is now high on the policy agenda, as in many other sectors, policy, as well as institutional and human resources development, are challenged to keep up with the sheer pace of change and social oversight is weak.

But this broad picture obscures great variation. China does not in fact have one food system. Instead, multiple forms of production and consumption coexist and interact with each other, sometimes, but not always, overlapping in physical space. Production varies from highly mechanized large-scale agriculture to small-scale integrated farming, with the latter including both traditional (but still post-collective) and modern organic, green or no-harm varieties. Despite indications of convergence between rural and urban areas, consumption patterns also vary enormously across regions, income groups and age cohorts. These different production and consumption activities have complex implications for food safety and for the way in which concerns about food safety interact with producer livelihoods and the affordability of food to consumers. On the governance side, the capacity to monitor and regulate food safety also varies considerably across jurisdictions as do public awareness and willingness and capacity to pay.

Although the broad contours of China's food safety problems and the challenges they present are clear, addressing them will require more detailed knowledge of the way problems manifest themselves across different regions and populations and with regard to different products, as well as of the policy mechanisms and resources available and needed to address them. In the context of ongoing urbanization and industrial restructuring it will be necessary not only to identify existing problems but also to anticipate and prepare for change.

Although the specification of a detailed research agenda is beyond the scope of this report and would require the participation of experts from many disciplines, below we make some general recommendations emerging from this project for clusters of research that would be helpful in informing both policy responses and public understanding and oversight.

7.1 Integrated analysis of existing data

The information base for assessing health risks from food is currently very limited, and does not adequately capture the risks associated with specific products, populations and localities. Most data collection is undertaken by different disciplinary and policy streams (health, environment, agriculture, etc.) with no coordination and little sharing across agencies. The strengths and weaknesses of different data sets are rarely explained in a way that is accessible to non-expert users, and experts from one agency or discipline are not always aware of the existence of relevant data from other sources.

This report has provided a brief analysis of some of the main data sources (see Appendix 1), but it would be helpful to conduct and publish a systematic analysis of relevant data sets (including sampling frames and variables covered) in order to determine where there may be the potential for integrated analysis that could help to identify patterns of potential food safety risks. For example, there may be cities, counties or other administrative units for which existing data from different sources can be matched in order to more effectively assess or anticipate food safety problems.

Even when data cannot be directly matched, discussion of the findings from different data can be helpful in identifying priorities. For example, it would be helpful for the health sector to have a more detailed understanding of where recent soil pollution studies show potential risks to health from heavy metals in food so that these could be priorities for health monitoring and service provision. Within the health sector, discussion of the way in which dietary patterns and nutritional and general health status interact with food safety risks could also be helpful in targeting dietary advice and, if necessary, subsidies or alternative food supplies to particular populations.

Convening cross-disciplinary and cross-agency workshops would be necessary to work out priorities for joint analysis and what can feasibly done in light of current constraints of data and the technical and institutional barriers to sharing it.

7.2 Supplementing regular data collection

Currently, most sampling frames for regular data collection do not reflect the distribution or trends in the underlying drivers of food safety problems, and new data collection that links to these is also needed. Some of this could be done by adding sites, populations or

variables to ongoing monitoring and surveys. For example, the TDS could be conducted in counties and cities that reflect not only different dietary patterns but also typical combinations of environmental conditions, agricultural production and food processing that may affect food safety. This could help to identify emerging risks in particular locations and inform targeted monitoring and policy responses. For example, in broad terms it is possible to identify areas where food safety risks are likely to stem from the coexistence of agriculture and mining or heavy industry, or from the rapid development of animal husbandry or aquaculture.

More systematic linking of macro- and micro-level data would also be helpful. Currently these levels of analysis are largely disconnected and do not fit well together. In-depth case studies of food safety have focused on products or places in which problems have occurred or have been conducted in major cities. In the absence of publicly available findings from larger scale research, such case studies are often used to draw inferences about the prevalence of food safety problems. These can be misleading because the sites are not chosen to reflect the underlying distribution of risks and their drivers, and the ways in which they vary across contexts, including different modes of production, different types of market conditions and different consumption patterns.

However, the true value of case studies lies not in demonstrating the prevalence of food safety problems but in their potential to unpack the ways in which natural and social systems interact to generate risks and the roles of different actors, institutions and market and policy incentives. Case studies that are designed to illuminate how these processes play out with regard to common constellations of problems, signficant differences in the organization or scale of production, or different market or policy environments can help in understanding why problems arise, where possible levers of change may lie and what resources or incentives would need to be in place to make change possible.

Ideally, analysis of large scale quantitative data and qualitative case studies should inform and complement each other, but they often occur separately because the disciplines and funding streams involved are different (macro studies being conducted mostly by environmental and health scientists and case studies by economists, development studies or other social science researchers). More funding is becoming available for interdisciplinary projects, but the expense and challenges of management will make such projects the exception rather than the norm. The experiences of the EcoHealth Network and of the Forum on Health, Environment and Development suggest that a network approach that emphasizes cumulative learning and systematic referencing of other disciplinary knowledge is probably the most feasible way to build an interdisciplinary knowledge base and incubate collaborations on specific issues (Holdaway 2013).

Below we highlight a number of issues that deserve priority for research, with a focus on questions that involve interactions between physical and social systems and that require an

interdisciplinary approach.

7.3 Understanding spatial and demographic variation

Food production does not take place in a vacuum, but in many places coexists with other activities including industry and mining that can present risks to food safety through soil and water pollution. Different modes of agricultural production can increase or decrease risks from these activities; for example, soil acidity and quality, which are related to modes of agricultural production, affect the bioavailability of heavy metals. Horticulture-animal husbandry interactions also have implications for food safety; for example, heavy metals and veterinary drugs in animal feed and animal waste can affect food crops through soil and irrigation water, while meat and fish can accumulate chemicals from pesticides and other chemicals used in horticulture.

A better understanding of the implications of common clusters of productive activity for food safety and their regional distribution would be useful in informing policy and helping local governments and communities to assess and reduce potential risks. For example, in the case of heavy metals it is possible to envisage designing a check list that would enable local government or communities to gauge the level of potential risk in their area and prioritize action (see Table 3). Because even relatively small industries or mines can present a problem if soil quality is poor and staple foods are involved, preliminary research suggests that this kind of assessment needs to be done at the township level. At the same time, certain populations may also be vulnerable to particular food safety risks as the result of poor nutritional status, lack of access to affordable safe food, or dietary preferences. A better understanding of how risks are distributed across demographic groups would allow for more effective interventions and risk communication.

7.4 Interactions between industry expansion and upgrading and food safety

There is quite a strong consensus among researchers in mainstream Chinese research institutions as well as many outside observers that increasing production scale provides benefits for food safety in terms of mechanization, managing agricultural inputs, providing technical support and simplifying regulatory oversight. Creating higher value chains is seen as another way to enable better food safety management, sometimes, but not always, in combination with an increase in the scale of production. But there is evidence to suggest that relationships between scale, value and safety are not straightforward and that even if positive synergies can be attained, certain conditions must exist for this to happen.

For example, research on the beef, milk and aquaculture industries shows that market incentives and policies that promote the rapid expansion of product sectors can put pressures on producers and processors of foods that encourage unsafe practices. Even policies that are intended to ensure quality (for example, the protein content standard for

milk and requirements for slaughterhouses) can have unintended negative consequences if the technical capacity to meet them is lacking, supply and demand are out of balance, or if meeting requirements will involve higher costs in a tight market.

More detailed investigation of the way in which the development and expansion of different product lines interacts with food safety issues would be helpful in understanding the point in the supply chain at which problems may occur for different products and the technical and other capacity requirements associated with different production scales. Product sectors that are experiencing rapid expansion or intensification, or for which new standards are being set, should be priorities. Detailed understandings of the interaction between price and ability to meet standards would clearly be an important part of this research, especially for staple foods or products that have very tight profit margins.

7.5 Governance, stakeholders and intersecting policy agendas

Improving food safety in China will entail the participation of multiple actors within and beyond government. The recent reform has consolidated responsibility for food safety in the hands of a central China Food and Drug Administration. But identifying risks and implementing policy will continue to require collaboration between a large number of policy streams, including environmental protection, agriculture, water resources and commerce as well as health. It will be important to understand how food safety relates to the existing mandates of various agencies (for example food security and nutrition policy), to the organization of their administrative structures, and to evolving policy and programmatic priorities and related resource allocations. The way in which food safety intersects with these agendas and the human and financial resources available will affect how various government agencies frame and engage with different food safety problems, and needs to be understood if barriers to interagency collaboration are to be overcome.

7.6 Implementation, institutional and human resource development

Laws and regulations regarding food safety are now quite comprehensive and detailed. But capacity to implement them clearly varies considerably by region. A better assessment is needed of existing institutional and human resources (for example technical personnel) for assessing and addressing food safety risks at various points along the food supply system and of the resources that would be needed to bring capacity for implementation to a certain level within particular time frames. For example, many county-level environmental protection and health agencies are currently under-staffed and/or have many staff who lack professional training in that sector. What are the short- and long-term needs for training in order to improve the effectiveness of staff in agencies working on various aspects of food safety?

7.7 Evaluation of existing mechanisms for food supply chain management

A number of different models of producer-consumer linkages (both horizontal and vertical) have been developed in recent years to address food safety problems and increase trust, some through government initiatives and others on the initiative of producers or consumers. More systematic evaluation of the advantages and disadvantages of different models is needed, as well as consideration of which may be appropriate in different contexts. In addition to national initiatives, cities are also experimenting in this area. For example, Shanghai has attempted to introduce systems for controlling the supply chain, which may be relevant for other resource-rich cities but to date there is not much information available about the effectiveness of these measures or how cities with fewer resources are responding to food safety concerns.

7.8 Public awareness and responses

It is well known that public concern about food safety is high, but little is known about how public evaluation of different risks compares to expert assessments or how public spending and risk reduction behaviors relate to perceptions of risk. Better understanding of these would be helpful in informing risk communication.

In a situation where public trust in institutionalized mechanisms for ensuring food safety is low, the last few years have seen the rapid growth of interest in alternatives to traditional food supply chains. These mostly represent efforts on the part of urban consumers to establish direct relationships with farmers in order to ensure access to safe and high-quality food through community-supported agriculture, urban gardening, and farm-community linkages. Although these programs affect a relatively small number of people, when successful they can provide healthy food to urban consumers, promote environmentally friendly production and support farmers' livelihoods. More evaluation of the efficacy of different models and possible room for expansion would be helpful.

Most of what we know about public efforts to secure safe food is based on studies of urban communities and relatively privileged consumers. Very little is known about perceptions of food safety and risk reduction behavior of rural and migrant populations who have less disposable income and fewer purchasing options.

7.9 International comparisons

Considering how China's food safety problems relate to international experience can be helpful in distinguishing which of the regulatory challenges involved are generic to the issue area and which to China's particular development trajectory, food cultures and governance system. Comparison may also be useful for understanding the timeframe

in which China can be expected to develop regulatory capacity with regard to different problems.

But in considering what China can learn from the way in which food systems are managed in developed countries, including those in Europe and North America and Australia, it will be important to take into account differences that may make similar approaches impossible (population in relation to land and water resources, for example). Furthermore, because the development of food safety management systems in the early industrialized countries was the result of long processes of negotiation between stakeholders and also required investment in infrastructure and enforcement capacity, looking at the process of policy development and implementation will be just as important as examining the finished product.

Although specific policies can be isolated for study in other contexts, it will probably be most useful to compare China either to large countries with high internal inequality (for example the US or EU as a whole) or to countries with similar food-related cultures (e.g. Japan or South Korea). At the same time it may be that on some issues, global management of food flows, rather than or in addition to national-level food safety regulation in rich countries, is a better place to look for ideas about how to improve food safety in the context of uneven development. The experience of the other BRIC countries and of later industrializers like Japan, South Korea and Taiwan, might also be helpful.

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APPENDIX DATA AND INFORMATION SOURCES

This Appendix provides an introduction to some of the major sources of information regarding food borne illnesses in China and the challenges in using them to understand food safety risks.

The impact of unsafe food on health can be assessed through data on the occurrence of food-borne or food related illnesses; data on dietary composition; data on food products, or data on production environments and inputs (WHO/FAO, 2006). One of the main sources of relevant data in China is regular government monitoring of environmental quality and health outcomes. The number of environmental pollutants that are monitored and the types of health data that are collected have both increased over the last ten years, as have the number of monitoring points. However, while this allows for more detailed analysis of the current situation, longitudinal analysis generally has to revert to a more limited number of variables and sites for which data is available for earlier years. Because sampling frames are different, environment and health data is hard to match up (FORHEAD, 2010).

Other data comes from special government surveys (zhuanxiangdiaocha) focused on particular issues of concern, which may be initiated by national, provincial or local governments. Because these investigations are driven by different agendas and conducted by different agencies and levels of government, they are rarely systematically analyzed in relation to national level data and sometimes are not shared with or known about by other agencies or researchers working on other policy streams. For example, the MEP and MOH have recently conducted a number of special studies designed to assess environmental impacts on health that include integrated analysis of environmental quality and health data in a number of sites. However little information is available so far about the sample or methods used, and it appears that these studies cannot distinguish exposure specifically through food as opposed to occupational or other pathways (Su & Cheng, 2014).

Other research is conducted by within universities, academies of social and natural science and government research agencies with funding from the national research foundations or international sources. Some of this research is initiated on the request of government agencies and local governments (many of which contract out to universities and academies of science due to their superior research capacity) but much is also driven by disciplinary agendas. These smaller studies can be very informative about the way in which problems manifest themselves in particular localities but the findings are often not generalizable (FORHEAD, 2010). Although no meta-analysis has been conducted, it seems that in the domain of food safety case studies are often carried out either in areas which are suspected

to have problems or in order to confirm that a certain food production environment is safe. If this is indeed so, it is likely that they capture the extremes of the distribution.

Health data

The Ministry of Health publishes data on incidences and deaths from food poisoning, distinguished by whether they are biological or chemical in nature (MOH, 2012b). However, it is generally acknowledged that due to underreporting these data do not provide an accurate sense of their prevalence: only 137 deaths of food poisoning were reported in 2011, with 14 attributed to microbial pathogens. It is unlikely that this reflects the actual incidence when the US with a much smaller population had more than three thousand deaths in the same one-year period (Lam, Remais, Fung, Xu, & Sun, 2013). Findings of bacterial contamination in food also suggest a higher incidence of disease (for example, Yang et al., 2011, found salmonella in between 39% and 65% of whole chickens from large small and wet markets in eight provinces). While the overall ability of the CDC to identify and trace the circulation of food borne pathogens including salmonella and shigella has increased due to the development of the PulseNet network (Xu, 2012), this will not necessarily provide much better information on the incidence of these diseases. As discussed in this report, the existence of antibiotic resistance strains is of great concern.

Other health data, including routine disease monitoring and cause of death data, do not shed much light on food safety problems that do not have rapid onset. Cancer and other non-communicable diseases in which diet plays a role have increased rapidly as a percentage of the burden of disease in both urban and rural areas (MOH, 2012a), and in some cases aggregate levels of pollution have been correlated with increases in cancer at the county level (Yang & Zhuang, 2013). But the contribution of unsafe food in relation to exposure through drinking water, occupational exposure, and overall dietary change and other behavioral factors can rarely be isolated. The generic difficulty in isolating the contribution of particular foods to disease is exacerbated in China by rapid changes in dietary composition and also by migration (Holdaway, 2014).

Total Diet Studies

Total Diet Studies (TDS) attempt to assess risks of chronic exposure by measuring the level of dietary intake of a number of heavy metals, pesticides and other chemicals and change over time based on typical patterns of food consumption. China has conducted five such studies since 1990 (Zhang, 2013; Zhou et al., 2010), with the last in 2012. However, TDS cover a limited number of chemicals and do not identify the presence of bacteria, parasites and viruses or veterinary drugs and growth promoters. Furthermore, while the TDS sample

distinguishes different regional diets, it does not reflect variation in the drivers of food-safety problems. For example, the early samples did not include Hunan, Yunnan or Guizhou, which have concentrations of heavy metal mining and processing industries and serious heavy metal pollution (Chen, 2013; Zhang et al., 2010). Although Shanghai and Liaoning are included, these samples also did not include other provinces such as Guangdong, Zhejiang and Jiangsu where industrial production has had a clear impact on the agricultural environment. The expansion of the sample to 20 provinces in 2009 will provide better data but longitudinal analysis will remain limited for some time, making it hard to assess the impact of policy interventions.

Food purchasing and consumption data

Food purchasing and consumption data can also provide indications of trends in food safety risks associated with certain types of products. The China Health and Nutrition Survey (CHNS) has been conducted by the National Institute of Nutrition and Food Safety, the Chinese Center for Disease Control and Prevention (CDC) and the University of North Carolina at Chapel Hill since 1989. It reports foods that are consumed and their nutritional composition as well as the correlation with various health outcomes. The findings are publicly available at www.cpc.unc.edu. China's National Statistical Bureau (NSB) reports household food purchases but does not cover food eaten outside the home.

Data from product testing

Another potential source of data is from the testing of products at some point in the chain from farm gate to retail sale. Inspection at the end of the chain, or at least in final destination wholesale markets, has the advantage of potentially allowing for testing of multiple kinds of hazard. Testing at the farm gate or in product specific wholesale markets allows for more targeted sampling and economies of scale in the use of equipment and personnel training, but only captures problems specific to that stage in the production chain. Different types of testing are carried out by public agencies and private businesses at various stages and the development of more effective testing regimes is an important part of food safety policy initiatives. Currently, however, no comprehensive data on the frequency of inspection or substances tested is available for products destined for the domestic market. Individual studies suggest that testing is irregular at best (Ma, 2012). Studies are underway to evaluate the coverage and effectiveness of inspection and testing in Beijing (Ma, 2012) and other cities. The findings of some individual studies relating to particular problems are discussed in the relevant sections of this report.

Production environment data

In the absence of data on health outcomes and product testing, data on production and processing environments and inputs are often used to estimate levels of possible exposure through the food chain. These include data on levels of chemicals of concern in soil, water and air; pollution emission levels; use of pesticides, growth hormones, animal feed and other agricultural inputs. However, because of the many intervening variables it is often not possible to establish a direct relationship between these data and risks to health through food. For example, because certain crops more easily absorb heavy metals than others, and soil quality also affects uptake, levels in soil do not directly translate into food safety risks. Equally, not only the quantity but also the timing of the use of pesticides and veterinary drugs is important in determining the likelihood of their remaining in or on food. (See FORHEAD, 2010, for a discussion of these data, which are collected by a number of different ministries through regular monitoring and special surveys.).

Law enforcement data

Another potential source of information regarding the prevalence of various kinds of food safety problems is the legal system, and records kept by ministries of complaints and public protests. Although deliberate food crime is a source of great anxiety among the public, we know very little about its extent and media reports that focus on serious cases may give an exaggerated sense of its frequency. One study (Cheng, 2012) that attempted to assess the occurrence and causes of food crime based on a survey and interviews in Zhejiang found the use of illegal levels of pesticides, colorants and the sale of out of date foods to be very prevalent, but the sample is small. Other information comes primarily from sectors in which serious problems have come to light, such as the dairy industry. Although both the earlier Food Hygiene Law, the 2009 Food Safety Law and the general Tort Law all provide for civil litigation to secure compensation for defective food products and also hold managers of markets and retail operations responsible for failure to inspect (Balzano, 2012) there does not appear to be any data available on the number and outcome of civil litigation or on criminal prosecutions and punishment for food related offences.

More generally, pollution-related health problems are increasingly the cause of complaints, lawsuits and mass protests (van Rooij, 2010; Dong et al., 2011). According to MEP statistics, 56 of the 232 relatively large (grade III and above[11]) environmental incidents that occurred between 2007-2011 involved cases in which environmental pollution caused damage to health (MEP, 2012). However, it is not clear how many of these related to food safety as

11.The MEP "Reporting Methods for Sudden Environmental Incidents" categorizes Grade III incidents as those in which pollution causes at least three deaths or more than 10 cases of serious poisoning; necessitates the moving of more than 5000 thousand people; causes direct economic losses of more than 5 million RMB; causes serious damage to protected animal or plant species; results in the interruption of concentrated drinking water supplies at the township level; involves environmental impacts due to the loss, theft or loss of control of three types of radioactive substances; or has impacts that cross municipal boundaries (MEP, 2011, author's translation).

opposed to perceived health threats from air, water or noise pollution. Some cities have now established hotlines for complaints regarding food safety which, if the data is made public, could provide a new source of data about poisoning and other acute problems.

Data on governance capacity and resources

Lastly, as discussed further in the policy section, although many studies point to the fact that the capacity to enforce food safety policy is weak, there is very little systematic information about this. The health sector has a National Disease Prevention and Control Basic Information System that collects information on human resources (including educational level and specialty), equipment and disease monitoring capacity that might be used to assess relevant capacity (FORHEAD, 2010) but in general studies that seek to assess capacity gaps have tended to use standard indicators of investment in health services such as the number of hospital beds and indicators of total investment in environmental protection (for example, Su & Duan, 2010).

Availability of data

The situation in terms of access to data is quite complicated. Some data are officially stated to be secret by the national government or a particular ministry, as with the 2006 soil pollution study. But a lot of data exist in a semi-public state, where certain findings are known and circulated, but the raw data itself are not accessible, restricted to certain agencies or provided at a level of aggregation that is not useful in assessing risks to particular populations or regions (as for example statistics concerning the percentage of arable land polluted by heavy metals). Even when numbers are available, information regarding sampling methods is often lacking, making it difficult to assess the significance of findings.

While the media tends to focus on the availability of information to the public, it is clear that the government itself is struggling with a lack of data, especially when it comes to assessing problems that involve the interaction between different policy jurisdictions and monitoring systems. The MEP Work Plan on Environment and Health in the 12th Five-Year Plan summarizes the challenge of data with regard to environmental impacts on health as follows, and it seems the situation for food safety is quite similar:

> …no nationwide or large regional investigations into environment and health have been conducted in our nation. …there is no clear baseline information about the geographic distribution of the health impacts of environmental pollution, about the extent of damage to health, or about the evolution of trends. This not only makes it difficult to distinguish the most hazardous environmental factors, and propose effective measures for responding, but also to conduct an assessment of

health risks related to environmental pollution, make timely adjustments to policy, and propose targeted measures for dealing with [problems]). (MEP, 2011)

Media reports as a data source

In this context, media and NGO reports play a key role in shaping public perceptions of the scale and nature of food safety problems. Studies of environmental awareness and complaints more generally have found that media reports are by far the main source of public information (Liu et al., 2011; Dong et al., 2011). What is less commonly recognized is that they are also an important source of information for the government. In addition to providing information about potential actual hotspots of disease, media reports flag places and populations where public perceptions of disease, sometimes in combination with other factors, are creating social conflict and generating demands to which the government feels it must respond. However, media coverage emphasizes certain problems over others, with a preference for crisis situations and problems with a high "dread risk factor" (Slovic et al., 1979) over less dramatic problems. For example, media attention to illegal additives far outweighs that which is given to problems associated with the overuse of veterinary drugs, although these almost certainly present a much greater threat to public health. As it does in other countries, the bias in media coverage causes certain risks to loom particularly large in the minds of the public (Holdaway, 2013).