

Pig in the Middle: Environment, Health and Development Dimensions of the Pork Sector in China

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Abstract

This article introduces this special issue, which draws on research by an interdisciplinary team of environmental, health and social scientists to examine the ways in which pig farming in China impacts the environment, human health and rural livelihoods. It traces the evolution of pig farming in China, from early times when pigs were a crucial part of the household-based, integrated agricultural economy, through the waves of changing policies towards livestock rearing in the Mao era, to the encouragement of household pig farming as a means of rural development after reform and opening up. It then discusses concerns about the environmental and health impacts of pig farming and the policies that have been introduced to address them in recent years. Throughout, the analysis emphasizes the ways in which regional variation in environmental conditions and economic structure creates different local challenges and needs for targeted policy approaches that balance environmental and livelihood concerns.

Keywords

Pig Farming, Rural Livelihoods, Environment, Health, Sustainable Development

1. Introduction

This collection of articles considers the multiple dimensions of China's search

for sustainable agricultural development through the lens of the pig, unpacking the economic, health and environmental impacts of changing modes of pork production and consumption. Pigs, it turns out, are “in the middle” of many of the dilemmas facing China as it attempts to transition from a development model focused on maximizing growth, and ensuring basic livelihoods and food security, to a cleaner, higher value and sustainable agricultural and food system. In this introduction, we provide background for the articles that follow by discussing these intersecting challenges and the ways in which policy has responded to them over time.¹

The collection is the work of an interdisciplinary working group of the Forum on Health, Environment and Development (FORHEAD), a network of researchers from the natural, health and social sciences who since 2008 have sought to bring an interdisciplinary perspective to research on interactions between environment, health and development in China (Holdaway, 2010; Holdaway et al., 2010). Since 2012, we have been exploring the multiple challenges presented by the transformation of China’s food system as well as interactions between agriculture and other forms of production including mining and industry (Zhang, Holdaway, & Wang, 2019; Holdaway, Wang, & Zhang, 2018; Holdaway, 2015; FORHEAD, 2014; Chen, Cheng, & Luo, 2013, 2020).

In 2016, we formed a working group to examine in more depth interactions among the various dimensions of the environmental, development and health impacts of the pork industry. Although our research was informed by a broad food systems perspective, we did not examine every link in the chain from farm to fork, but instead focused on production and consumption in order to illuminate interactions between livestock rearing, environmental impacts and rural development at one end, and the role of pork in diets and human health at the other. We have sought to understand how important pig rearing is for rural livelihoods in China, the environmental impacts that piggeries of different scale have in different contexts, and the place of pork in the Chinese diet and culture.² We have also examined policies from different streams and their effectiveness in managing this complex set of environmental and health challenges.

2. From Food Security to Sustainable Diets

For a long time, particularly in developing countries, the focus of agricultural policy was on ensuring food security in the traditional sense of a sufficient supply; and when the environmental impacts of food production were considered, it was mostly in terms of the impact of crop farming or grazing on grasslands, or the depletion of water resources. Over time, however, the multiple, interconnected impacts of food production on the environment and on human

¹This is not intended to be a literature review, but to provide a broad brush picture of the evolution of problems and policy responses.

²Four articles by the team are published together in this special issue. Additional research on Nanping County in Fujian Province, conducted by Su Shipeng and his colleagues, is in the process of publication elsewhere but we refer to the case where relevant. See also Du et al., 2020).

health have become apparent. A growing literature on sustainable diets stresses that consumption is important not only in terms of the direct effect of what we eat on our health but also through environmental impacts created by demand, including excessive resource use, pollution (Blair & Sobal 2006; Marlow et al., 2009) and climate change (Hyland, Henchlon, McCarthy, & McCarthy, 2017).

The livestock sector has attracted the attention of environmental and health researchers because of its heavy environmental footprint and the growing evidence that meat is linked to the development of chronic diseases and other health risks, including zoonotic diseases and antimicrobial resistance. Globally, the water footprint of animal sourced food is 29% of total water footprint of agricultural production (Mckonnen & Hoekstra, 2012) and Greenhouse Gas (GHG) emissions from the livestock sector account for about 15% of human-induced emissions worldwide, and half of all those from agri-food systems. (Beef, cattle and milk accounted for 41% and 21%, while pigs added 9% and poultry 8%) (Gerber et al., 2013). While the link to obesity and diabetes is debated, consumption of red meat and especially processed meat has been linked to a range of cancers (WHO, 2015) and the widespread use of antibiotics in livestock production is a factor in the emergence of antimicrobial resistant bacteria (WHO, 2018).

It is now clear that the health and environmental impacts of food production need to be addressed in an integrated fashion. The most recent addition to the debate is the “Planetary Diet” proposed by a team of scientists in 2019, which would address the climate change and health threats by encouraging a radical shift from meat-to plant based diets (Willett et al., 2019). But almost a decade ago the United Nations’ Food and Agricultural Organization (FAO) defined “sustainable diets” as “diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations”. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and health, while optimizing natural and human resources (FAO 2010). Other institutions, including the World Resources Institute, have also contributed to the effort (for example, Ranganathan, 2016). Research is now exploring how such a synergy can best be achieved between nutrition and environmental sustainability (Ausetad & Fulgoni, 2015; Buttriss & Riley, 2013; Hyland et al., 2017; Perignon et al., 2017; Rööös et al., 2015; Van Dooren et al., 2014; Westhoek et al., 2014) although so far only a few countries have nutritional guidelines that incorporate environmental sustainability: Brazil, Germany, Qatar, and Sweden (FAO, 2016).

3. Variation in Production and Consumption and the China Case

While there may now be a consensus on the importance of an integrated, systems approach to sustainable agriculture and diets, the way in which the environmental, health, economic and socio-cultural dimensions of sustainability in-

teract varies widely as the result not only of different levels of development and environmental conditions but also dietary practices. For example, levels of meat consumption vary enormously, from a low of about 3 kg per person a year in India in 2018 to almost 100 kg in the United States (OECD-FAO, 2021). Furthermore, the type of meat consumed is shaped not only by the availability of pastureland or other natural conditions but also by cultural factors including religion. Hinduism has a taboo against the consumption of beef, as Islam and Judaism do for pork; many Hindus and Buddhists follow a vegetarian or mostly vegetarian diet. Guidance on sustainable diets therefore has to be tailored to specific contexts.

China is a crucial case because the size of its population means that even small changes in production and consumption directly affect more than 1.4 billion people and have a huge impact on the global environment and the burden of disease. There is quite an extensive literature on some dimensions of sustainable agriculture and diets in China. Studies of China's food system have highlighted the environmental impact of meat production and its implications for health (Garnett & Wilkes, 2014). Food safety problems related to meat production, including the threat of AMR have also been documented to some extent (Larson, 2015; for a summary of earlier research see FORHEAD, 2014). The pork sector was the topic of two reports by the Institute for Agriculture and Trade Policy (IATP), one focusing on feed (Schneider, 2011), and the other on industrialized pork production (IATP, 2014). Mindi Schneider has also analyzed the ways in which changes in pork production reflect larger shifts in global agriculture (Schneider, 2018) and China's post-reform development strategy (Schneider, 2017). Other research has focused on the environmental impacts. A 2015 special issue of *Agriculture, Ecosystems and Environment* focused on nutrient management, with the livestock sector highlighted as a major source of direct and indirect air and water pollution (Norse & Ju, 2015; Smith & Siciliano, 2015) and recommendations made for addressing it (Chadwick et al., 2015)

. Pigs contribute less to greenhouse gas emissions than cows or sheep, making up only 9% of emissions from the livestock sector, which accounts for 14.5% of all emissions (Gerber et al., 2013). However, the massive scale of production means that the pig industry in China has been estimated to contribute a third of all emissions from the sector globally, from methane produced in the process of enteric fermentation and nitrous oxide from manure (Dai et al., 2021).³

In China, the diversity of the natural environment and uneven development means that a wide variety of traditional and modern agricultural practices coexist and the same animals are raised in different ways under very different environmental conditions. For example, the overall problem of China's tight population-to-land ratio is well known—it must feed a fifth of the world's population with only seven per cent of the world's arable land, while water resources are approximately 2000 cubic metres per person annually, compared with a global average of about 6200 m³ (World Bank, 2012). But these resources are unevenly

³This does not include emissions from the production of fodder.

distributed and their spatial interaction has implications for the sustainability of the livestock sector in different regions. For example, grasslands suitable for the pasturing of ruminants are concentrated in the North and Western provinces, which also have sparser populations, while land suitable for the production of cereal grains commonly used for feed are concentrated in the densely populated central regions. Water resources are most plentiful in the south. The distribution of these natural resources, along with differences in climate—the north has freezing temperatures in winter, while the south is temperate or tropical—create different challenges and kinds of tradeoffs for the sector, as we shall see.

The dietary situation is also complex. Meat consumption (pork, beef and lamb) has increased steadily as incomes have risen, from 16.4 kg per person in 1990 to 31.5 in 2021 (OECD-FAO, 2021). However, China's dietary structure is still quite distinctive and there is considerable regional variation within the country. Although pork dominates in terms of the national average, at 23.7 kg per person in 2021 (OECD-FAO, 2021), pork is of varying importance in different regions. National Bureau of Statistics data for 2020 show that pork consumption is highest in Sichuan (28 kg per capita), Guangdong (24 g) and other Southern provinces and lowest in the northwest and other areas with large Muslim populations; it is only 3.4 kg per capita in Xinjiang (NBS, 2020). As we shall see, the role of pork production in rural livelihoods and cultural life also varies considerably across the country (see the articles by Chen, Gong and Yang, Fang, and Yang and Zhang in this special issue).

This environmental, economic and cultural diversity needs to be unpacked in order to understand the environmental and health impacts of different agricultural practices and different diets and consider how diets might be made more sustainable from both perspectives. We hope that this collection of papers makes a start in this direction. The remainder of this introduction provides some historical background and a discussion of the overarching policy context.

4. Traditional Pigs?

Pigs have a special place in Chinese culture and society. The character for “home” is a pig under a roof (家); the character 豕 (*shǐ*) means pig, and so a “home” is basically a house that has a pig in it. The character appears in this form in the ancient oracle bone scripts of the late second millennium BCE, which indicates that pigs were already domesticated at this time. In some parts of China, pigs really did live under the family roof, on the ground floor of the house or in a sty right next to it. Domesticated pigs provided food security and fertilizer for crops, and so became the symbol of settled residence. The pig is also included among the twelve animals of the Chinese horoscope, with the year of the golden pig regarded as particularly auspicious. The head of the mythical Chinese dragon (龙 *long*), also derives from the pig. All this reflects the centrality of pigs in the traditional Chinese rural economy, in which they served not only as a major and highly valued source of protein, but also as an efficient source

of fertilizer for cropland, oil for cooking, and leather and bristles.

Although the economic reforms of the late 1970s are usually seen as a turning point between “traditional” and “modern” forms of animal husbandry, there were many shifts in the practical and symbolic role of the pig prior to this, and historical research on pork production and consumption has some surprising findings. For example, pork is now the staple meat in most parts of China and if there is no animal qualifier, the word for meat (肉 *rou*) is generally assumed to refer to pork. But this was not always the case. In his analysis of early food and agricultural texts, Kuo (2013) found that before the Song-Yuan era, when China’s political and economic center of gravity moved South, lamb rather than pork was the “mainstream” meat. When the Song Dynasty official and poet Su Dongpo was exiled to Huangzhou in Hubei Province in 1080, he wrote that the pork was delicious. However, “rich people dislike eating pork, yet the poor know not how to cook it....” (Kuo, 2013: p. 46). The famous pork dish, Dongpo Rou, was of course later named after him.

Meanwhile, although there is regret these days at the rapid disappearance of “traditional” pig breeds and concern over their replacement by fat, white, American counterparts, a process Schneider (2018: p. 235) terms the “foreignization” of the pig herd, it turns out that the history of pigs’ migration is also complicated. Studies of mitochondrial DNA show that around 1700, Chinese pig breeds were imported to Britain and Northern Europe, because after years of husbandry they were easier to raise, and fattened more quickly than European swine, which were semi-domesticated foragers resembling wild boar. In 1800, an observer remarked that “By a mixture of the Chinese black Swine with other of the larger British breed, a kind has been produced which possesses many qualities superior to either of the original flocks. They are very prolific, are sooner made fat than the larger kind, upon less provisions...” (Bewick, 1885, cited in White, 2011: p. 107). A similar process occurred in the United States, where in 1799 a commentator remarked, “The Chinese hog mixed with the American old breed of white hogs... gives an excellent breed, which is hardy, feeds cheap, and weights 160 to upwards of 200.” (Bordley, 1799 cited in White, 2011: p. 108). Chinese pigs were therefore participants in the later development of the industrialized pork industry in the United States (White, 2011) and it is their partial genetic descendants that have more recently been reintroduced into China.

5. Collective Pigs and Capitalist Pigs, 1949-1978

While Chinese pigs were participating in the agricultural revolution in Europe and the United States during the 18th, 19th and early 20th centuries, back in China household rearing remained the norm and the total number of pigs was low. Between 1912 and 1935 the stock of pigs in China increased 25.2%, reaching more than 78.5 million in 1935, the highest since 1911. After this, the destruction of war led numbers to fall to below 58 million by 1949 (Li, 2004: p. 115). In that year, total production of pork, beef and mutton combined was only 3.4 mil-

lion tons or 4 kg per person per year (NBS, 2002). That works out at 77 g a week or just over 10 g per day. But that level of consumption was not even across the population: many people would have eaten no meat at all or enjoyed it only at Chinese New Year. The larger context was of course that food of all kinds was in short supply and hunger widespread after years of war and internal conflict.

The period from 1949 to 1978 saw a series of policy swings, as the Communist Party repeatedly changed its position on the balance between household and collective agricultural production. The pork sector was affected by policies that stipulated how pigs should be reared, by policies related to grain production and also by the impacts on household life of repeated waves of collectivization and de-collectivization. After the founding of the PRC, pigs were raised mostly by farmer households and stocks recovered rapidly, reaching more than 100 million by 1954 (Ministry of Agriculture, 1989). But in the following two years numbers dropped again by almost 20 million. The organization of agricultural cooperatives, which reached its peak in 1955, sidelined individual pig farming, making no arrangements for the provision of fodder and the sale of manure. The policy of the unified procurement and sale of grain (粮食统购统销 *liangshi tonggou tongxiao*), introduced in 1953, meant that when grain harvests were poor, peasants in some regions did not have enough grain for themselves, let alone their pigs (Huang, 2007: p. 13).

The fall in pork production attracted the attention of Chairman Mao, who in a 1956 speech stressed the importance of integrating agriculture, forestry and animal husbandry. He observed, famously, that “a pig is basically a small organic fertilizer plant” and called for cooperatives to ensure that there would be “One pig per person, and one pig per *mu* of land” (General Office of the CPC Central Committee, 1956). On July 1, 1956, the State Council issued a Notice on Developing Pig Rearing, which specified the approach of “private ownership, private rearing and public assistance (“私有、私养，公助” *siyou siyang gongzhu*) The proportion of fodder the state reserved for peasants increased, and the area allocated for private plots was also expanded, so that peasants could grow fodder for livestock as well as vegetables for themselves. Prices for pigs went up, and in 1957 pig stocks increased to 146 million (Ministry of Agriculture, 1990).

Yet by 1961 there had been another dramatic downturn. Stocks were down to less than 76 million, and the number of pigs sold was half that of 1952. This was in large part the result of policies related to the Great Leap Forward, which affected traditional family pig farming in multiple ways. The first was by drawing workers out of agriculture to take part in steel production and rural construction projects. Combined with natural disasters, this withdrawal of labor resulted in a dramatic fall in grain production from 1959 to 1961 to an average of only 433 *jīn* per person; 170 *jīn* less than in 1957 (NBS, 2010). Meanwhile, communal canteens not only used a lot of grain, but meant that peasants no longer cooked in their own homes, so there were no leftovers for the pigs. Private plots and animals were also taken back into the collective during this time. In 1957, collective

pigs in Hunan accounted for only 6% of the total, by 1958, they were 99%. But collective pig farms also lacked feed and management expertise, and disease spread, causing a high rate of mortality that contributed to the fall in production (Li, 2004: p. 115).

In 1961 a series of policies were rolled out to reduce the burden on peasants, including compensation for land that had been taken, restoring private plots, and permitting sideline production and trading in local markets. Procurement quotas for grain were lowered and in January 1961, the Secretariat of the Central Committee of the CCP changed the approach to pig rearing to “public and private rearing proceeding together, with the emphasis on private rearing” (公养私养并进, 以私养为主 *gongyang siyang bingjin, yi siyang weizhu*) Production teams were instructed to give commune members land to grow feed and encouraged the sale of feed grain. Production recovered, reaching 193 million head by 1966, and pork consumption reached 7 kg per capita (Huang, 2007: p. 21).

With the onset of the Cultural Revolution in 1966, pig production entered another slow period. Under the slogans “One more piece (fen) of private land is one more selfish thought”, some localities reduced the land allocated to private plots from 7% to 5%. Criticizing people for “emphasizing the individual and neglecting the collective”, some production brigades went so far as to forbid commune members from rearing pigs, while others restricted numbers. Rural markets were considered to be “capitalist free markets” and were closed, restricting trade in pigs. Stocks fell, from 193 million to 173 million in 1969 (Huang, 2007: p. 22).

In 1969, the Ministry of Agriculture concluded that neglect of individual pig rearing and unstable incentives were responsible for the drop. With Mao’s approval, the 1970 National Meeting on Agriculture, Commerce and Planning Work decided that from 1971, grain procurement quotas should be set for five years. Grain production increased, and the end of year stock of pigs increased from 206 million in 1970 to 264 million in 1972. There were further upheavals in the 1970s as natural disasters and criticism of capitalist legal rights again caused stocks to decline, but in the end the policy of encouraging private pig farming held. In 1979, the Central Committee’s Decision on Several Issues Regarding Speeding up Agricultural Development” called for promoting the livestock sector and the approach of “actively developing collective pig farming while continuing to encourage private pig farming,” which had been in effect since 1970, was revised to “continue to encourage commune households to raise pigs and sheep, and actively develop collective farming of pigs, cows and sheep.” This gave peasants the right to decide for themselves what kind of animals to raise and in what numbers. In 1979, the State Council increased the purchase price for pigs by 26.7%, and the price per 100 *jīn* rose to 62.69 yuan, where it remained until 1983 (Han et al., 1992: p. 272). In 1980 a regulation allowed farmers to sell animals over the fixed government purchase quota on the market and in 1985, the system of fixed government purchase of pigs, which had lasted for 30 years, was abolished. All pigs could be freely sold on the market (Huang, 2007: p. 33).

During this period, in keeping with the overarching emphasis on food security

and increasing the amount of protein in people's diets, the emphasis was on increasing pork production, mostly for local consumption. There is no good data on pork consumption specifically until the 1980s but estimates by [Du and colleagues \(2014\)](#) using data from the Bureau of National Statistics show the impact of roller-coaster fluctuations in pork production on consumption. In 1952, average pork consumption was just over 16 g a day, and although this fell slightly, consumption of all animal products rose over the next five years. Between 1958 and 1962, during the Great Leap Forward and its aftermath, intake of animal source foods fell by 42% to well below 1952 levels and only 16 g a day in rural areas ([Du et al., 2014](#)). This was only part of the larger disaster in which at least 30 million people died of hunger and many more were affected by serious malnutrition. By the early 1970s policies to promote the sector had shown effect. By 1972 pork consumption had tripled to reach 17 g per day, and the next decade would see it rise much more rapidly.

6. Pigs for Profit, 1978 to 2007

When land was contracted to households under the responsibility system in 1981, collective pigs went too, usually along with land on which to grow fodder. The production team's pigsties and tools were lent out to contracting households, who in return handed over a portion of their production. By 1982, peasant households accounted for 96% of all pigs ([Huang, 2007: p. 29](#)). Collective pig farms that were not dissolved also changed their operating systems, mostly by linking payment to output, sharing profits, or contracting out packages of production activities to households.

While there was a commercial pig rearing and ham production sector in pre-revolutionary China, centered primarily around the lower Yangtse region of Jiangnan ([Kuo, 2013](#)), it was only in the early 1980s that raising pigs in large numbers for sale beyond the locality became common. This was partly a function of demand: as China urbanized and hundreds of millions of city dwellers had to purchase food; and as incomes grew, consumption per head also rose. By 1982 urban pork consumption had already passed the level recommended in current nutritional guidelines of 40 g per day, although the urban population was still very small (the urbanization rate was only 20.9% ([China Statistical Bureau 2017](#)), and the rural average was far lower at just over 25 g per day. The problems currently associated with over-rich diets had yet to emerge. In 1982, only 5% of children were overweight and less than 1% were obese and 13.9% of adults were still underweight ([Du et al., 2014](#)). Chronic, diet-related diseases had yet to become an issue. Meanwhile, the volume of "waste" from the sector was still small and could be used locally and the use of antibiotics and other veterinary drugs and additives was rare.

The 1990s saw a continued increase in pork consumption and the closing of the rural-urban gap, as well as expansion in the scale of pig farming. By 1992, daily intake of pork had reached 37 g a day and by 2012 it had leapt by 73% to 64

g, or 21 kg a year. The increase in rural areas was particularly rapid, leaping from 25 g a day in 1992 to 60 g in 2012 (He et al., 2018). He and colleagues (2018) note that although meat consumption increased with income, it was higher per capita in provinces that were traditional meat-producing areas, including the relatively poor provinces of Guizhou, Yunnan, Sichuan and Inner Mongolia. At the same time, pork had decreased as a percentage of meat consumed. This was most pronounced in urban areas where pork fell from 91% of all meat consumed in 1981 to only 74% in 2003. The drop in rural areas was less pronounced, from 94% to 91% over the same period (He et al., 2018).

The expansion of the pork industry was also a strategy for poverty alleviation, both through the development of large-scale pig farms, and the encouragement of specialized households (*zhuan yehu*). In 1976, Beijing set up the first large-scale mechanized pig farm with 10,000 pigs, the Beijing Red Star Experimental Pig Farm. By 1979 several tens of large-scale mechanized piggeries had been built. Due to shortages of material, technical limitations, and irrational pricing (feed was expensive relative to the price of pork), production costs were high and only ten or so survived. In 1980, the first international joint venture pig farming enterprise was set up in Guangdong, using equipment from the United States and with an annual output of 80,000 pigs and by 1986, Guangdong had 82 farms that were producing more than 3000 pigs a year and 38 that produced 10,000 or more. Over the course of the 1980s, the state supported the establishment of bases in 16 provinces for the production of commercial pork. In 1989 alone, 329 such bases produced 111 million pigs (Lu et al., 1994).

Pork consumption rose rapidly during this period. By 2006, average per capita meat consumption had reached 140 g/day for urbanites and 120 g a day for rural people, three times more than current recommended guidelines of 40 g of meat a day (the guideline at the time was 75 g per day). Overweight and obesity had started to be flagged as public health problems, as chronic diseases started to dominate the burden of disease (Zhai et al., 2002). The Food Structure Reform and Development Masterplan for the 1990s (State Council of the PRC, 1993) continued to reflect concern with food security in terms of quantity and basic nutrition, emphasizing increasing the production of animal products, particularly ruminants that 'save grain', and poultry, which has a better feed conversion ratio than pork. The 1997 China Nutrition Improvement Action Plan also focused on addressing hunger and micronutrient deficiencies among vulnerable groups such as pregnant women, infants and the elderly, and set targets for addressing iron deficiency, anaemia and vitamin A deficiency (State Council of the PRC, 1997). To address anaemia, the government promoted animal-derived foods as a source of iron. However, in that same year, the China Nutrition Society, a government-supported NGO, laid out a set of dietary guidelines, in the form of a Food Pagoda, which advocated a relatively low intake of animal products of 25 - 50 g daily (Ge, 2011). At this time, the environmental impacts of the sector were still not a focus of policy.

7. Pigs Become a Problem, 2007-2017

As pork production and consumption have risen, the negative environmental impacts of livestock rearing and meat consumption have become painfully clear. From a climate point of view, it is fortunate that pork replaced lamb and beef as the major meat in the Chinese diet, because pigs have lower GHG emissions than ruminants, but absolute numbers still matter and pigs contribute 9% of China's GHGs.

Pig manure was a valuable resource in traditional integrated agriculture; several members of our group remember chasing after pigs to collect their droppings when they were growing up in the countryside and the majority of all pig manure was recycled as fertilizer. Now, in many but not all places, pig excrement and urine have become "resources out of place" (Taiganides, 1979) and as such are regarded as "pollution." The Communique of the First National Census of Agricultural Pollution Sources reported that in 2007 livestock and poultry sectors contributed 12.7 million tons of Chemical Oxygen Demand (COD) and 0.7 million tons of ammonia nitrogen discharge. In 2012, large scale livestock and poultry farming accounted for 95.8% and 78.1% of COD and ammonia nitrogen from agriculture, and 41.9% and 41.5% from all sources (Jin et al., 2022).

This is partly due to the sheer number of pigs in relation to land and water resources but it is also a function of the separation of livestock raising from crop farming and the replacement of animal manure with synthetic fertilizer, the use of which increased by four times from 1978 to 2012 (Carter et al., 2012; Chadwick et al., 2015; Sun et al., 2012). In 2010 about 3060 million tons of livestock manure was produced, of which about 80% was recycled and the rest dumped on land or in water. Even when applied to crops, manure is a problem if excess leaches into water bodies (Sustainable Agriculture Innovation Network, SAIN, 2012). By 2010 it came to account for 90% of COD, 38% of N and 56% of P discharges to surface water systems, causing eutrophication and acidification of the soil (Chadwick et al., 2015).

2007 saw a growing emphasis on environmental protection across the board and in 2008 the former State Administration for Environmental Protection was Upgraded to ministry status (The Ministry of Environmental Protection was renamed the Ministry of Environment and Ecology in 2018). The Law on Water Pollution Prevention and Control, which was revised in 2008, included a focus on non-point pollution from agriculture and livestock and protecting drinking water sources. However, observers have pointed to a disconnect between legislation and enforcement during this time (Chadwick et al., 2015) that is typical of the fragmented nature of much policy in China and partly a consequence of the interaction between the hierarchical, vertical operation of ministerial policy streams (*tiao*) with the horizontal organization of governance at different levels (*kuai*). Certainly, there was a clear tension between the mandate of the Ministry of Agriculture to expand production and that of the new Ministry of Environment Protection (MEP) to control pollution. Stronger environmental legislation also had to be enforced in a general environment in which economic growth was

still seen as taking precedence, which meant enforcement was spotty and intermittent (Chadwick et al., 2015). These challenges are discussed further in the article by Jin and colleagues in this special issue.

Around this time, concern also began to rise about the overuse of antimicrobials in the livestock industry to prevent disease among animals living in close quarters and to promote more rapid growth. Overuse of antimicrobials in animal husbandry can lead to the emergence of resistant bacteria that can spread to humans through animal products or environmental media. In 2010, livestock use accounted for more than 50% of all antimicrobial use in China (Zhang et al., 2015) and residues of antibiotics and other veterinary drugs had been found not only in meat but in vegetables and water bodies (Larson, 2015). Their presence showed concentrations consistent with patterns of production, with hotspots in Sichuan, Guangdong and coastal areas of South China (Van Boeckel et al., 2015). In 2017, China introduced a National Action Plan to Combat Antimicrobial Resistance from Animal Resources, 2017-2020, which focused on ending the use of antimicrobials for growth promotion, and in 2019 the Ministry of Agricultural and Rural Affairs announced its intention to end the addition of antimicrobials from feed (Hu & Cowling, 2020).

A number of zoonotic diseases are associated with pig rearing and/or pork consumption, including bacterial and parasitic infections. Pig-related parasitic diseases have decreased with the reduced consumption of raw pork and improvements in general sanitary conditions. However, other pig-related zoonoses have been increasingly reported within China in the last two decades, including the outbreak of *Streptococcus suis* infection associated with the slaughter, preparation or consumption of pigs in Sichuan in 2005 (Yu et al., 2006). Pigs can also become infected by some subtypes of Influenza A Viruses (IAVs), which are transmissible from bats, wild birds and domestic poultry to mammals. Some seven IAV subtypes are known to be shared by pigs and humans (Mostafa et al., 2018). Influenza A Virus subtypes, particularly H1N1, have been endemic in pigs since at least 1918, and warnings of the potential risk of a pandemic were raised as early as the early 1990s (see Ma et al., 2018). In 2009 a reassortant of H1N1, known as swine flu, developed into a pandemic. Early findings from an ongoing study in Jiangsu and Shandong on farms with 310 to 2500 pigs on site found that H1N1 type viruses were circulating among both the animals and the workers (Ma et al., 2018). Other pig diseases, such as the outbreak of African Swine Fever in 2018, do not affect humans but have caused severe losses to the pig population: although only 13,355 pigs died of the disease itself, more than 1.2 million were culled in attempt to prevent its spread (You et al., 2021).

8. Nutrition and Health

Concern over environmental impacts and food safety has been accompanied by growing attention to the role of meat consumption as a contributor to obesity and non-communicable diseases. The Chinese Residents Nutrition and Chronic

Diseases Report 2020 shows that the overweight and obesity rates for children aged 6 - 17 were 11.1% and 7.9%, while for adults over 18 the rates were 34.3% and 16.4% (China Nutrition Society, 2021), a substantial increase over 2010-12 (NHFPC, 2015). Overweight and obesity are major contributors to mortality from chronic diseases, including cardio and cerebrovascular diseases, cancer and chronic respiratory diseases, which accounted for over 80% of deaths in 2019 (China Nutrition Society, 2021).

Of course, pork is not the only factor in this, but in recent years, public health experts have pointed with growing anxiety to dietary patterns in urban and even rural China that show the same trends towards greater meat consumption as those in rich countries. By 2015, although it showed a slight decline from its peak of 89.7 g in 2012, average daily consumption of meat and poultry, at 85 g per day, was already almost double the level recommended by the China Nutritional Society, which is 250 - 280 g per week or only 40 g per day (China Nutritional Society 2021). The 2021 Chinese Residents Health Diet Guidelines reports Global Burden of Disease data showing that excessive consumption of red meat to be the 7th highest ranking contributor to cardio- and cerebrovascular diseases in China and recommends reducing the dominance of pork as the major source of animal protein and replacing it with more poultry, fish and seafood (China Nutrition Society, 2021).

Health policies have also gradually shifted their emphasis. The 12th Five-Year Plan for Control of Chronic Disease addressed for the first-time diet-related chronic diseases and called for raising awareness and the implementation of healthy lifestyle campaigns. Targets were set to reduce adult and child obesity to 12 per cent and eight per cent, respectively (Ministry of Health, 2012). In 2014, the State Council issued the Food and Nutrition Development Outline for 2014-2020 (State Council of the PRC, 2014: p. 3). The document pointed to the coexistence of under and over nutrition and the need to coordinate production and consumption with a focus on priority products and regions. It set targets for lowering fat intake and reducing obesity as well as child stunting. It also encouraged the development of traditional (soy and other bean) products along with dairy and livestock. In 2015, the Chinese Residents' Nutritional Guideline was released, which provides advice on what nutrients are commonly deficient in particular populations and how to eat healthily, as well as how to reduce dietary fat to around 25 - 30 per cent (NHFPC, 2015). However, although it calls for strong policies in agriculture, processing and distribution, most of the measures relate to public health education relating to personal consumption, which is within the jurisdiction of the health system. Improving dietary practices, including limiting consumption of meat, remain priorities in the Healthy China Action Plan for 2019-30 and the 2021.

9. Rural Livelihoods and Economic Sustainability

The above account has focused on the environmental and health implications of the shift from a situation in which pigs formed part of an integrated agricultural

system and pork was an important part of the diet but a luxury, to one in which crop production and animal husbandry are separated in many places and pork consumption is higher than considered healthy. This section considers the impacts of this change on another important issue: the role of pig farming in rural livelihoods.

Pigs were a small but vital link in the rural household economy in the pre-collective period, and when land was contracted out to individual households as part of the reforms of the late 1970s, many households again began to raise pigs; by 1985, almost 95% of pigs were raised by individual households. With urban demand rising, the government saw the potential for animal husbandry as a development strategy and actively promoted the sector. By 1996, the percentage of pigs reared by “specialist households” (*zhuan yehu*), had increased to 14.6%, up from only 2.9% in 1985.

Chen, Gong and Yang (2022) discuss this transition in more detail. As their analysis shows, the subsequent increase in pork production and consumption has been accompanied by a shift towards larger scale production that has had significant impacts on rural livelihoods. Their analysis of the 1st and 3rd Agricultural Censuses shows that the percentage of rural household raising pigs has fallen from 130 million in 1996 to just over 34 million in 2016 - a drop of 75%. At the same time, the average size of farms has increased, with 37% of production now in facilities with more than 200 pigs. As discussed further below, this shift reflects not only growing demand, but also changes in labor market incentives and government policies that support scaling up.

This shift means that most rural households are no longer dependent on pig rearing for their economic survival. At the same time, Chen, Gong and Yang’s analysis of provincial level differences, and the case studies by Fang Jing in Yunnan, and by Su Shipeng’s team in Fujian, show that the falling dependence of rural households on pigs is not evenly distributed. It is generally the poorest families in the poorest provinces that are still engaged in small scale pig farming and for them it can be an important contributor to their cash income. Their consumption of pork, already lower than for most, also falls when they stop rearing pigs. Research in Nanping County, Fuzhou, shows that a rapid transition out of farming can be wrenching in areas where it has been a pillar industry and the Yunnan case shows the cultural significance of pig farming (Fang, 2022). As with environmental impacts and nutritional concerns, the socio-economic context of pig farming and the implications of shifts in the organization of production both need to be understood on a local level.

10. Summary of the Articles

The first article in this collection, by Chen Chuanbo, Gong Yuying and Yang Lichao sets the stage with a macro level account of China’s pork industry and its relationship to rural livelihoods. It traces the evolution of pig rearing in China from integrated small holder farming, through collectivization, reform to the present day. The focus of the article is on understanding the changing signific-

ance of pigs in rural livelihoods and, as noted above, it finds that although the percentage of farmers who derive a significant percentage of their incomes from pigs is small, they are concentrated in the poorest provinces. The drop has also led to a huge labor transfer out of the sector. In 1996, 95% of pigs were still reared by individual households and more than a third of agricultural households bred pigs. By 2015, only about 14% of rural households were raising pigs and 800 million had left the sector, with those who remain now mostly participating in “farmer-enterprise” arrangements in which they fatten piglets for the market. Chen, Gong and Yang explain this as the result not only of government policy, but also of changing economic incentives for rural households, in particular the rising opportunity costs as rural workers had the opportunity to earn higher wages if they migrated for work. At the same time, the commercialization of production has made rising costs and prices fluctuations harder to absorb, and environmental regulations have entailed outlays for pollution control that most individual farmers cannot afford. These trends provide the backdrop for the case studies by [Fang Jing \(2022\)](#) and [Yang and Zhang \(2022\)](#), which illustrate the way in which the same constellation of incentives and constraints can play out quite differently in different local circumstances.

The article by Jin Shuqin and colleagues examines responses to the environmental problems presented by pig rearing from the environmental and agricultural policy streams, and the ways in which they have supported and contradicted each other. They focus on the Regulation on the Prevention and Control of Pollution from Large-scale Livestock and Poultry Rearing (PLLP), which was introduced in 2014. They trace the evolution of regulation back to the 2001 Administrative Measures for the Control of Pollution from Livestock and Poultry Rearing, which included technical discharge standards and standards for facilities in terms of flooring, prevention of leakage, etc. This was followed from 2004, by efforts to formulate regulations and provincial level implementation plans with local discharge standards. However, it was not until 2014 that the national Regulation was finally issued. It requires assessment of local environmental carrying capacity and impact assessment and bans livestock raising in ecological fragile areas, giving local environmental protection bureaus at the county level or above the power to shut down or demolish illegal facilities and requiring them to do so by the end of 2017. Where it is allowed, it requires the “comprehensive utilization and treatment” of waste through biogas and organic fertilizer production with a target of 75% reuse by 2020 (National Plan for Agricultural Modernization 2016-20). However, drawing on fieldwork in five provinces (Anhui, Zhejiang, Sichuan, Heilongjiang, and Fujian), the authors point to some difficulties in implementing these ambitious goals that result from insufficient integration of policy making and implementation across the agriculture and environmental streams. Some problems relate to the different standards and definitions of scale used by the MOA and the MEE, and even in different documents issued by the same ministry which result in inconsistent targets for the treatment of pollution and the reuse of waste. Others are the lack of consideration of local en-

vironmental conditions (for example the availability of water and climate factors) in the government's promotion of the relocation of pig farms from Southern to Northern China (see also Jin et al., 2022), as well as technical problems connecting clean energy sources to the power grid. Underlying some of the problems is a fundamental difference in the way that the two sectors regard pig urine and excrement, with agriculture seeing it as a resource, and the environmental protection sector as a "pollutant" that needs to be controlled. Again, the work of this team suggests that finer grained analysis is needed to improve policy integration at both the central and local level.

The case studies of pig farming in different regional contexts that follow illustrates the ways in which these tensions play out under different socio-cultural, economic and environmental conditions, approaching the issues from the disciplinary perspective of the authors, which include public health, rural sociology, anthropology and public administration. The article by Fang Jing discusses a county in a mountainous area of Yunnan Province. It is an example of a community in a poor region of Southwestern China where small-scale pig farming still predominates, but many changes have taken place in the way that pigs are raised. In the 1970s, most household raised two pigs, one for their own consumption and one for sale. These indigenous black pigs took a year to reach maturity and were fed on wild grasses and scraps. From the late 1970s the government promoted pig farming as a poverty alleviation strategy and the agricultural extension system introduced hybrid pigs that grow faster and produce more meat. Although farming is small scale, with most farmers raising an average of only 36 pigs in 2014-5, most of them do not breed pigs themselves but buy piglets and raise them to maturity, and farming techniques are somewhat industrialized, with farmers using commercial feed, paying for artificial insemination and using antibiotics. Although the costs of buying inputs is higher, and profits can be as low as 100 - 200 yuan per pig, less labor is needed, and most of the work is done by older people, especially older women who have few other opportunities, so they can absorb price shocks by temporarily halting production. However, the changes have brought new problems; the area is in the water source catchment for Kunming City but a lot of waste is untreated. In addition to pollution, the higher density of animals has increased disease risks. Farmers seem unaware of the risk of AMR and often use animal antibiotics without prescriptions. They also sometimes use human antibiotics to treat sick pigs, believing that animal diseases are not transmissible to humans. Yet, in the midst of change, some traditional practices survive. Most farmers prefer to feed pigs they will eat themselves in the traditional fashion, for the taste, but also because they think that pigs fed commercial feed will make humans fat, too. Pigs also feature prominently in local cultural traditions, with the annual Pig Killing Feast (*shazhufan*) around the time of the lunar New Year, and even families who do not rely on pigs for income will raise a couple of pigs for their children working in the city and for *shazhufan*.

This second case study presents an interesting contrast. It is also a poor rural

county, but one that is located south of Datong, in Shanxi province. This area has a mixture of mountainous and flat terrain and the custom for hundreds of years has been to raise pigs in the hills and grow grains on the plain, along with cow and sheep herding. Although pig farming was also strongly encouraged from the late 1970s, and the county now produces more than 100,000 pigs a year. the scale falls in the middle range of the spectrum, and only a couple of villages have facilities with more than 500 pigs. However, the scale is still much larger than the county in Yunnan, with few households raising fewer than 100 head. Unlike rural areas of the south, pig rearing is not currently linked to poverty alleviation; most of the families that raise pigs are in the upper half of the income spectrum. But income from pig farming is still important to them, making up around half their income, and there are not many alternative opportunities, particularly as people in the area are disinclined to migrate for work. The market is relatively stable because the meat is sold locally, to meet the demand for fatter pork and because households mostly raise pigs in their own yards and have an economic cushion, they can ride out fluctuations. However, many farmers noted that government subsidies had disproportionately benefited richer households with more resources to invest. In terms of the environmental impacts, although the scale of individual farms is large compared to Yunnan, because most of the piggeries are less than 500 head, they do not fall under the regulation of the EPB. Despite this, the environmental impact is low because there is high local demand for manure and waste water as fertilizer for agriculture, creating a circular economy. From 2007, the county implemented a biogas project, with significant investment from the province but this was unsuccessful because winter temperatures are too low in the North, and the manure would not ferment. There was also little demand for biogas because villagers use *kangs* (heated brick beds) and heat them while cooking, and their minimal other electricity use is also subsidized. The locals in this site do not seem to place the same kind of cultural significance on pigs as in Yunnan; they are happy to eat pigs fed commercial feed and do not raise pigs separately for their own consumption. Raising pigs is seen as a fairly reliable livelihood that is not too tiring and allows them to stay at home, which is a plus at a time when opportunities for construction and other work locally are declining.

11. Reflections on Multi-Dimensional Sustainability

The articles in this collection explore the complex interactions between different dimensions of sustainability as they relate to the pork industry, and the way in which they vary across time and space. Collectively, they challenge the common assumptions that many poor people are dependent on pig farming, that small farms are the most polluting and that smallholders are the most vulnerable to price fluctuations. It turns out that while these may be true in some cases, it depends very much on the specific circumstances. Factors including the relationship of pig-farming to other livelihood activities, the demographic structure of the local population, the extent to which waste can be recycled locally as well as

the nature of the markets into which smallholders sell all interact to produce different outcomes.

The articles also consider how governance challenges are evolving as environmental protection has moved up the government's list of priorities. For example, where analysis of the reasons for excessive chemical fertilizer use by [Smith and Siciliano \(2015\)](#) focuses on inadequate enforcement and the continued "growth-first" mentality of local government, the research by Jin Shuqin and others in this collection shows that the problem is now not so much under-enforcement as inappropriate enforcement and problems of weak policy coordination, along with insufficient adaptation of policy to specific environmental and social conditions. These cases show that scale alone does not determine the environmental impact of farming. Local ability to recycle animal excrement and urine as fertilizer is also important, as the Shanxi case shows. Although one might expect the scale of the farms there to result in serious environmental pollution, the combination of the cold, dry climate and the strong market for organic fertilizer meant that this was not the case. However, the same factors meant that the large investment made by the government in biogas in that area was wasted, showing that solutions that are effective in one place may be inappropriate elsewhere.

This research also shows how necessary it still is to consider the importance of pig farming to rural livelihoods and which populations will be most seriously affected by restrictions, including different age and gender cohorts. Although it is true that the majority of poor farmers no longer depend on pig farming for their livelihoods, there are pockets of rural China where sizeable concentrations of people do, and in these places, rapid, rigid policy implementation in the absence of supportive measures for vulnerable families can cause serious social dislocation and may exacerbate inequality within communities as well as across regions (see [Du et al., 2020](#)).

Since we started this project several years ago, policy has moved on, but unfortunately the COVID pandemic has made it impossible for the team to conduct follow up fieldwork. It would have been helpful, for example, to assess the implementation of recent policies to reduce the use of antimicrobials. For our interdisciplinary team, the Rural Revitalization program, launched at the 19th Congress of the Chinese Communist Party in 2017, is also particularly interesting. As [Jin et al. \(2022\)](#) point out, not only does the "2018-2022 Rural Revitalization Strategic Plan" state that the sustainable development of China's animal husbandry is crucial to rural development and the restructuring of China's agricultural economy, but it also emphasizes coordinated and integrated progress across several policy spheres and balancing economic development with environmental protection and improvements in public health. In principle, this multidimensional approach to sustainability should help to address some of the tensions between different policy streams described in this collection and we look forward to following its implementation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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