Sustainable maize production and consumption in China: practices and politics in transition

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Sustainable maize production and consumption in China: practices and politics in transition (accepted for publication in *Journal of Cleaner Production)*

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Abstract

China provides a stark and globally significant illustration of how changing patterns of food production and consumption (especially related to increased intake of animal protein) are creating negative impacts on biodiversity, climate, nitrogen and phosphorous cycles and the use of freshwater. However, China's rapidly growing innovation capabilities and dynamic pattern of development also offer a unique opportunity for transitions towards more sustainable and resilient agri-food systems. Applying a 'food practices in transition' framework (Spaargaren et al 2012), this paper discusses the technological, political and socio-cultural factors central to such systemic changes, with a focus on maize as a core case study. In particular it presents and discusses two contending (but not mutually-exclusive) pathways towards more sustainable maize production and consumption. One, which we call the 'indigenous innovation' pathway is framed by 'systemic rationalities' and characterised by a focus on R&D-intensive technologies for agricultural intensification, including the controversial use of transgenic phytase maize. The second, which we term the 'alternative' pathway, is framed by 'lifeworld rationalities' and focusses on improved management practices, shorter supply chains, agro-ecological and participatory research. The two pathways claim different environmental benefits and present different risks and political implications. This paper analyses the food practices in transition in each pathway, identifying links with shifting political conditions and pointing to the increasingly significant role of consumer agency in steering patterns of maize production and consumption in China.

Keywords: low-carbon innovation, China, transitions, practices, agro-ecology, maize, agriculture, pathways to sustainability

Highlights

- Introduces two pathways to sustainable maize production and consumption in China
- Analyses the "food practices in transition" that each pathway implies
- Investigates political debates surrounding each pathway
- Considers implications of Chinese food practices for shifts in production and consumption

1. Introduction

The latest assessment report of the Intergovernmental Panel on Climate Change (IPCC 2014: 19) states "continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems." At the same time, beyond climate change, earth systems scientists have proposed broader "planetary boundaries" on sustainable development: arguing that interacting anthropogenic changes to nitrogen and phosphorous cycles, freshwater use, biodiversity and land-use change, among others, threaten to bring unpredictable turbulence and tipping points, undermining the patterns of human development seen over the past 10,000 years (Rockström et al 2009; Steffen et al 2015). Alongside these biophysical constraints, broader understandings of *sustainability* can be understood as situated within the everday lives of people and communities, leading to framings of sustainability that are more closely associated with social concerns around poverty alleviation and justice (Leach 2010). It is now recognized that transformative innovation of many different kinds is required to bring patterns of global development within the "safe operating space" determined by these planetary boundaries in a way that simultaneously addresses poverty alleviation and social-justice imperatives (Leach et al 2012).

Since the 1990s, the sustainable development literature has recognized the contribution of innovation to both environmental performance and competitiveness (Porter and van der Linde 1995) within a "green techno-economic paradigm" (Freeman 1996). Western European nations started to invest in research and development for emerging environmental technologies, and environmental innovation assumed a place in the industrial strategies of many states. Scholars have since begun to recognise the role of the state in strengthening both supply and demand in order to enhance eco-innovation (Rennings 2000; Mazzucato 2013).

At the same time, other scholars focusing on broader sustainability transitions have in addition looked at more bottom-up, 'grassroots' or citizen-led contributions to systemic change (Seyfang and Smith 2007), pointing to the importance of everyday routines, changing consumer practices (Shove and Walker 2010) and cultural framings of sustainability (Spaargaren 2011) in enabling or constraining transitions. This has raised questions about the links between consumer practices and citizen action in driving political change and the wider role of politics in transitions (Meadowcroft 2009),

Following similar shifts towards green industrial policies, emerging Asian economies such as China have over the past decade begun to assume competitive positions in strategic environmental sectors (Ely and Scoones 2009; Altenburg et al 2008; Lema and Lema 2012; Schmitz 2013). Calls for 'indigenous innovation', such as in China's Medium-Long Term Plan for Science and Technology (2006-2020), align R&D investments and incentives in strategic emerging industries with the country's efforts to address environmental imperatives. While studies of the Chinese government's approach to managing eco-innovation now commonly appear in the international literature, key neglected areas of research include the political synergies and tensions between the

managerialist approach to creating internationally-competitive sectors (requiring the development of technological capabilities, alongside appropriate supply-side and demand-side policy interventions) and the uncertain and unpredictable socio-technical and socio-political reconfigurations and socio-cultural change that are intrinsic to sustainable socio-technical transitions.

Western scholars have begun to pay more attention to the role of narratives, institutions, interests and practices as components of the political realities underlying or constraining transitions (Kern 2011; Verhees et al 2013; Lockwood 2013; Smith et al 2014), however this remains a relatively under-researched area. Responding to this gap in the literature, this article investigates emerging transitions in agri-food systems in China in order to understand how different forms of innovation relate to changing practices among various groups of producers and consumers, as well as how they are supported and constrained by political debates in the country's changing policy-making environment. Mirroring the multiple understandings of 'sustainability' outlined above, China's radically shifting food system not only requires decarbonisation, but also requires innovation to address some of its other associated environmental and social challenges – including nitrogen and phosphorous pollution associated with current agricultural approaches, food safety, food security and food sovereignty. We adopt a 'food practices in transition' framework (Spaargaren *et al* 2012) in our analysis, drawing also on insights from the multi-level perspective on socio-technical systems (Geels 2002; Geels and Schot 2007) and the pathways approach (Leach *et al* 2007; 2010) to understand how different framings of potential transition pathways link socio-technical innovation, governance and, in particular, the role of changing consumer practices in China. Applying these concepts to empirical evidence from China for the first time provides insights into the shifting relationship between consumer practices and transitions to more sustainable agri-food systems, raising important questions for food system governance in the country.

Within our focus of sustainable food consumption and production, we analyse two transition pathways that are both linked by maize, a key staple Chinese food and feed grain with a long history in the country. These pathways centre around:

1) The centrally-supported development of genetically modified (GM) phytase maize as a potential component of intensive agri-food (including livestock) systems, and;

2) The emergence of agro-ecological and low external input sustainable approaches to the production and consumption of maize and associated agricultural products.

Beyond innovations in maize itself (in terms of seed and cultivation), these pathways incorporate shifts in other components of the agri-food system (Spaargaren et al 2012) notably in socio-technical innovation, policy and regulation, and the socio-cultural aspects of consumer practices. The article examines each of them, drawing upon multiple sources of documentary (Chinese and English language) and interview evidence (detailed in Section 2) to examine the pathways and their linkages to China's broader agricultural transition.

Section 2 first provides a deeper background to recent changes in the agri-food systems in China, including shifting patterns of production and consumption and some of their associated environmental and social impacts. To help us understand these changes, it introduces the theoretical framework and the methodology adopted in the paper, with a focus on 'food practices in transition'. Section 3 introduces the two case study pathways in question and a summary of the secondary and primary (documentary and interview) data upon which the analysis draws. Section 4 looks at the role of politics and practices in both 'indigenous innovation' and 'alternative' pathways. Finally, in Section 5, we discuss the implications of these findings for our broader understandings of practices and politics in transitions studies. Importantly, this points to the hitherto neglected, but increasingly central, role of social practices and the "green public sphere" (Calhoun and Yang 2007) in China's agri-food transitions, an area in which we pose a number of key questions for future research.

2. Food Practices in Transition: A Theoretical Framework for Understanding China's Shifting Patterns of Production and Consumption

China is home to around one-fifth of the world's population, but only 8% of its arable land. Famine, scarcity and rationing are all-too-recent memories for the country's leaders and many of its people. Feeding China is hardly a matter of policy alone: the Chinese government sees avoiding food scarcity as one of its highest priorities in order to maintain political legitimacy, public trust and social stability. National policies around food and agriculture focus on production (Ma and Adams 2014, 53), including investments in chemical fertilisers, pesticides, irrigation and high-yielding seed varieties (Schneider and Sharma 2014, 13), as well as the use of strategic reserves and export restrictions for staples. At the same time, rising demand means imports have risen significantly (Garnett and Wilkes 2014, 104), both for food and feed (serving the increases in meat consumption to which we turn later).

Industrial agriculture is a major contributor to climate change: one estimate from the World Resources Institute (see Figure 1) suggests the agriculture sector accounted for 8% of China's greenhouse-gas emissions in 2009. The manufacture and use of synthetic nitrogen fertilizer accounts for some 9% to 15% of China's total greenhouse gas emissions (SAIN 2011a), and for every tonne of nitrogen fertiliser manufactured and used in China, 13.5 tonnes of CO2-equivalent gases are emitted, compared with 9.7 tonnes in Europe (Zhang et al 2013). These impacts are apparent even before one considers the climate-change effects of wider transitions in the food retail sector, particularly the "supermarketisation" of food retail (Hu et al 2004; Reardon et al 2005; Oosterveer 2012) and its relationship to changes in food storage (such as refrigeration), food transport and imports, patterns of urbanization and changing mobility practices.

European scholars have studied trends in agri-food systems over the past 50 years, pointing to the post-war industrialization of agricultural production. Through interactions with clusters of other factors (including patterns of consumption and developments in the retail sector) that – together – have contributed to wider systemic transitions. According to Spaargaren *et al* (2012, 4) "transitions are medium to long-term (from about 10 up to

50 years or so) processes of change which… affect the regimes, e.g. the specific rules of the game of food production, retail and consumption. Transitions refer to structural changes resulting in the emergence of new modes of production and consumption." Adopting 'practices in transition' as a key explanatory concept, Spaargaren *et al* chart the interaction between new framings of human-environment interaction, socio-technical innovations and changes in regulatory and governance conditions.

These ideas around socio-technical transitions mirror and build upon concepts of system innovation (Rip and Kemp 1998; Elzen et al 2004), which recognized the interaction between technologies, cultural change, policy and regulations and market structure. Systemic interpretations have been refined to produce a 'multi-level perspective' (Geels 2002) focusing on the shifting configurations of nested landscape, regime and niche levels of organization of the socio-technical systems. While the emphasis on 'culture' and 'user preferences' (Geels 2002) recognizes consumers as important actors, it can oversimplify the role of consumer citizens in both supporting niches (in terms of providing market demand, as discussed by Oosterveer and Spaargaren 2012) and actively constructing them (in terms of entrepreneurship, idealistic experimentation, advocacy or other forms of agency, investigated for example with respect to UK organic farming by Smith 2006). Instead, documenting the "consumerist turn" in the more recent understanding of shifts in European agriculture (in keeping with reflexive modernization), Spaargaren *et al* adopt practices as a central feature in their analysis.

Transitions, therefore, can be seen to involve the reciprocal interaction between changing opinions, beliefs and wider socio-cultural frames of the actors involved (not only consumers but also regulating authorities, farmers, managers and workers in the food industry, retailers and marketing specialists): "they change their views, positions and tactics on food within a delineated period of time while addressing a set of issues they all deem relevant for the future of food" (Spaargaren et al 2012). Cultural framings of sustainability (Spaargaren 2011) are also emphasized in the pathways approach (Leach et al 2010) that investigates the ways in which interacting social, technological and ecological systems evolve over time. Leach *et al* point to different framings of system components, boundaries and the functions that systems perform for the actors in question (including analysts, policy-makers, consumers and citizens), highlighting that these different framings lie at the heart of sustainability politics at local, national and international levels. Dominant managerialist framings can serve to narrow understandings of complex sustainability challenges, leading to policies that shape directions of social and technical change in ways that – while addressing some overarching policy objectives – may undermine more marginalized and locally-applicable pathways to low carbon development (Byrne et al 2011). In Spaargaren *et al*'s (2012) terms this highlights the difference between 'systemic rationalities' often evidenced among policy makers and producers and 'lifeworld rationalities' displayed among consumers. In this paper, we apply a similar framework and concepts to the changes underway in China, for the first time attending to consumer practices and consumer agency as the central analytical focus within the transition process.

Methodologically, this paper adopts a case study approach to explore the interactions

between changing consumer practices and wider transitions. In the next section, we go on to describe in detail two potential pathways (Leach et al 2007) for maize characterised by the case studies listed in section 1, examining the prospects for associated transitions to low-carbon and sustainable agri-food systems. Our analysis draws on 39 interviews, five of which are cited/ quoted in the text, that focused on politics and practices around both GM and organic/agro-ecological pathways for food production, distribution and consumption. These interviews, with eight scientists and experts, six farmers, three NGO activists and two private sector representatives, were conducted in Beijing and Guangxi province in 2014 and 2015. Participants were selected through snowballing for their relevance to the pathways detailed below: all participants had engaged with one or other agri-food system pathway. 20 further interviews were conducted with consumers, selected through convenience sampling at retail outlets in Beijing in 2015. All interviews, which typically lasted an hour, were semi-structured, but conducted according to an identical questionnaire focused on the politics and practices around maize agri-food systems. Five were conducted in English and the rest in Chinese; a research assistant acted as interpreter, where necessary, and Chinese transcriptions were translated into English. The analysis, which aimed to explain the empirical work through the theoretical lens of the 'food practices in transition framework' also draws on short-term participant observation at NGO and farmer-organised meetings in both sites. Beyond these methods, the paper draws on both focused and exploratory literature reviews around respectively the case studies at hand and around the wider politics of food and agriculture in China, and reading of extensive documentary evidence from print and online media, civil society and government documents (Chinese and English language sources) directly related to the case studies. These sources were used iteratively alongside interviews to identify knowledge gaps (especially in advance of expert interviews), to identify and understand areas of political contestation, to help to triangulate across different accounts, if interview testimonies were unclear.

3. Two Potential Transition Pathways in Chinese Maize Production and Consumption Systems

Since 1980, average *per capita* meat consumption in China has quadrupled (Schneider and Sharma 2014: 11). In terms of the numbers of animals, China has seen a five-fold increase in pig stocks and an almost 9-fold increase in chickens since 1961 (FAO 2013). As maize is the country's primary feed crop (Zhang et al 2010), the rapid expansion of maize and meat production and consumption are intrinsically linked. Together, they have had a significant environmental footprint in China, in the form of carbon emissions, soil and water pollution. Maize requires more nitrogen fertilizer (with associated greenhouse gas production) than many other feed crops. Studies have found livestock waste is a large contributor to the substantial emissions of nitrogen, phosphorus and heavy metals, including copper and zinc, in China's water supplies, with manure responsible for 38% and 56% of the total nitrogen and phosphorus discharges into China's surface waters, respectively (Qiu 2010; Garnett and Wilkes 2014: 54). At the same time, management practices by small farmers and livestock owners exacerbate these problems. Overuse and inefficient use of nitrogen fertilisers is also common (Li et al 2012), with farmers often applying 30-60% more nitrogen fertilizers than required for

optimum yields (SAIN 2011b). Inorganic phosphorus is often added to pig and chicken feed, leading to more entering the environment as diffuse water pollution. A recent authoritative review has suggested that dealing with diffuse water pollution from agriculture cannot be dealt with by single regulatory or policy makers but requires a holistic approach, especially through farmer education and training (Smith and Siciliano 2015).

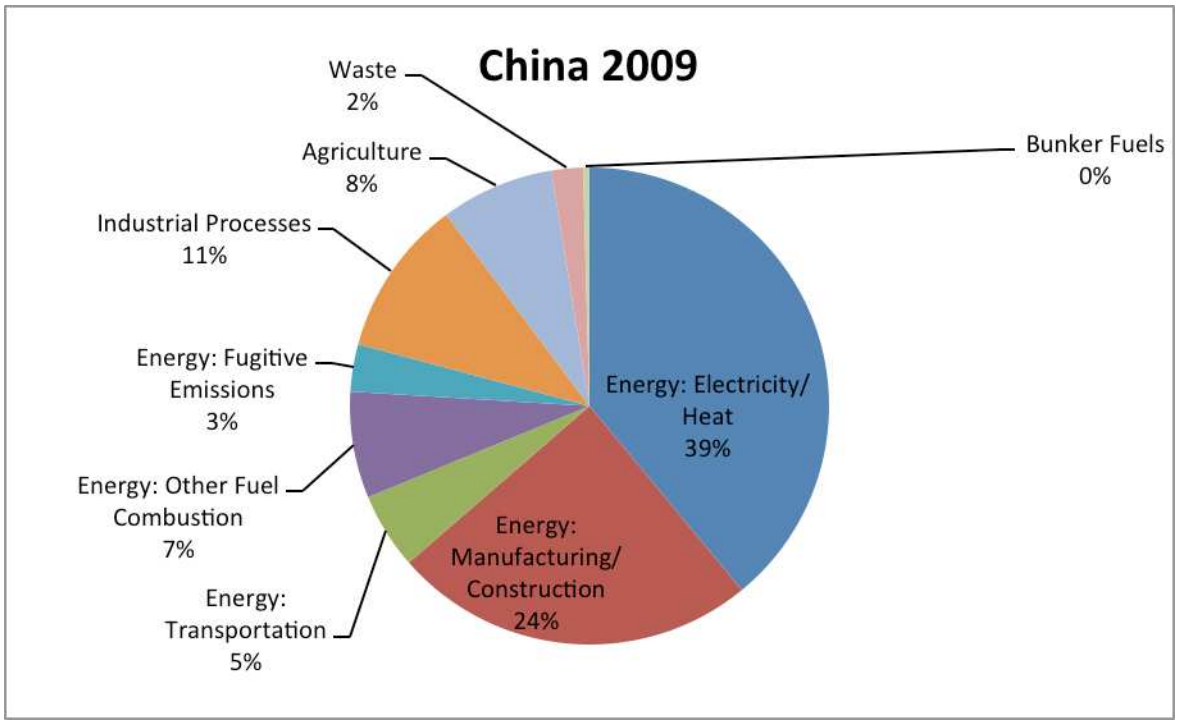

Figure 1: Greenhouse gas emissions in China by sector and energy subsector, 2009, World Resources Institute. (Chart excludes land use and forestry, since it is a net carbon sink)

China's rising meat consumption and production has had a significant impact on patterns of maize production and consumption. While 50 years ago, maize was grown on around 15 million hectares across China, by 2012, this figure had climbed to more than 34 million hectares for both food and feed (FAO 2012), with more than a 12-fold increase in annual overall production (see Figure 2). Of this maize crop, 68% is now grown for feed (see Figure 3). Intensive forms of maize production at increasingly larger scales use large amounts of synthetic inputs, such as fertilisers and pesticides, and produce additional carbon emissions through mechanisation (Burney et al. 2010). In the context of climate change, pollution and broader sustainability concerns, these trends evidently demand innovation and system transitions towards new models of maize production and consumption.

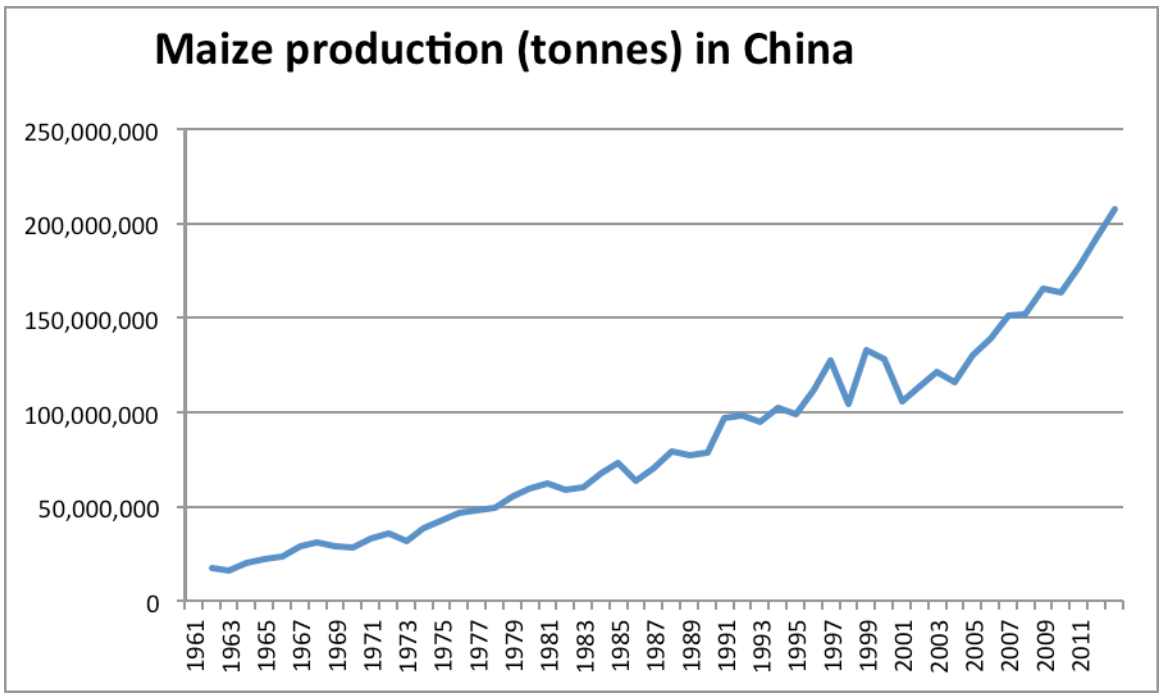

Figure 2: Maize production (tonnes) in China, 1963-2013, FAOSTAT data

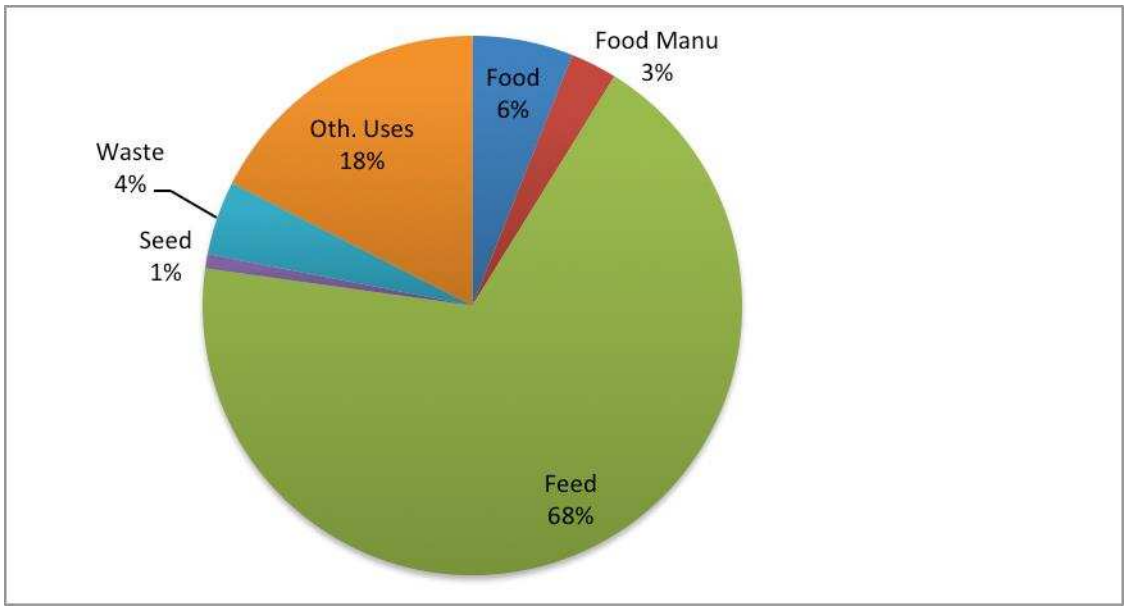

Figure 3: Maize utilization in China, 2009, FAOSTAT data

3.1. Indigenous Innovation and Phytase Maize

Phytase is an enzyme that breaks down phytates (chemicals that are found in maize and

act to inhibit the uptake of phosphorous as a nutrient in monogastric animals, such as pigs and chickens). Phytase is therefore often used as an additive for animal feed and is mandatory in Europe, Southeast Asia, South Korea, Japan and Taiwan, primarily because its use reduces phosphorous pollution from animal faeces (BusinessWire 2009). Transgenic high-phytase maize, which would theoretically eliminate the need for such additives by enabling livestock fed on the crop to absorb more phosphorous directly, is therefore argued by protagonists to have environmental and greenhouse-gas mitigating benefits, principally:

- Direct energy (and associated emissions) savings as a result of the active ingredient phytase being made in the plant rather than the factory. One of the scientists involved in developing the technology, Chen Rumei, has said: "If this technology is commercialised, we can save up to 450 million yuan (US$60 million) per year in energy costs used to produce industrial phytase enzyme additives." (SciDev.net 2009)
- Environmental benefits associated with avoiding pollution from phosphorus and other discharges. The firm that developed the maize claimed in 2008 that phytase increases phosphorus absorption in monogastric animals by 60% and reduces the release of phosphorus in faeces by 40% (Origin Agritech 2008).

In Spaargaren *et al*'s (2012) terms, these arguments demonstrate a "systemic rationality" whereby a technological substitution is able to improve performance while bringing environmental benefits. More broadly, Chinese policymakers see the role of this technology within a broader shift from small-scale towards industrial pork production, echoing a popular discourse that equates industrial agriculture with modernisation and development (Schneider and Sharma 2014: 22). Beyond this up-scaling of agricultural and livestock production, phytase maize also fits within China's industrial policy of fostering competitiveness in strategic environmental areas through "indigenous innovation".

Phytase maize was developed over seven years through publically funded R&D by the Chinese Academy of Agricultural Sciences and licensed to Origin Agritech Limited, a private Beijing-based agricultural biotechnology firm, which listed on the NASDAQ Stock Market in 2005 and specialises in research and development, production, sale and distribution of crop seeds, accounting for 7% to 8% of China's crop seed market. The firm claimed in 2008 that phytase increases phosphorus absorption in monogastric animals by 60% and reduces the release of phosphorus in faeces by 40%. It also claimed that the worldwide phytase potential market size was US$500 million, including $200 million for China alone, citing the China Feed Industry Study (Origin Agritech 2008). The company is an example of China's approach to supporting indigenous innovation through funding public R&D and the development of the private sector. Accumulating intellectual property (IP) is a key strategic aim and the firm, which has commercialized a range of proprietary seeds and holds IP (including a US patent) on a synthetic glyphosate-resistant gene for use in transgenic maize agriculture. Origin Agritech has received significant government support: for example, Origin's filings (Origin 2013) state it has received subsidies for R&D totalling 1.55 million yuan in 2012 and 16.11 million yuan in

2013, accounting for around 4% and 38% of the firm's total 37.63 million yuan and 42.16 million yuan R&D budgets in those years, respectively.

On November 27, 2009, the Ministry of Agriculture (MOA) granted a five-year biosafety certificate for field trials of phytase maize. However, before the product could be officially commercialised it needed to complete the seed variety registration process (GAIN 2009). Origin Agritech had said they hoped this would be completed in 2013, but in 2014 the authorities blocked the final approval process. We later discuss the political conditions under which these decisions were made in section 4.1, with a focus on the role of consumers and civil society.

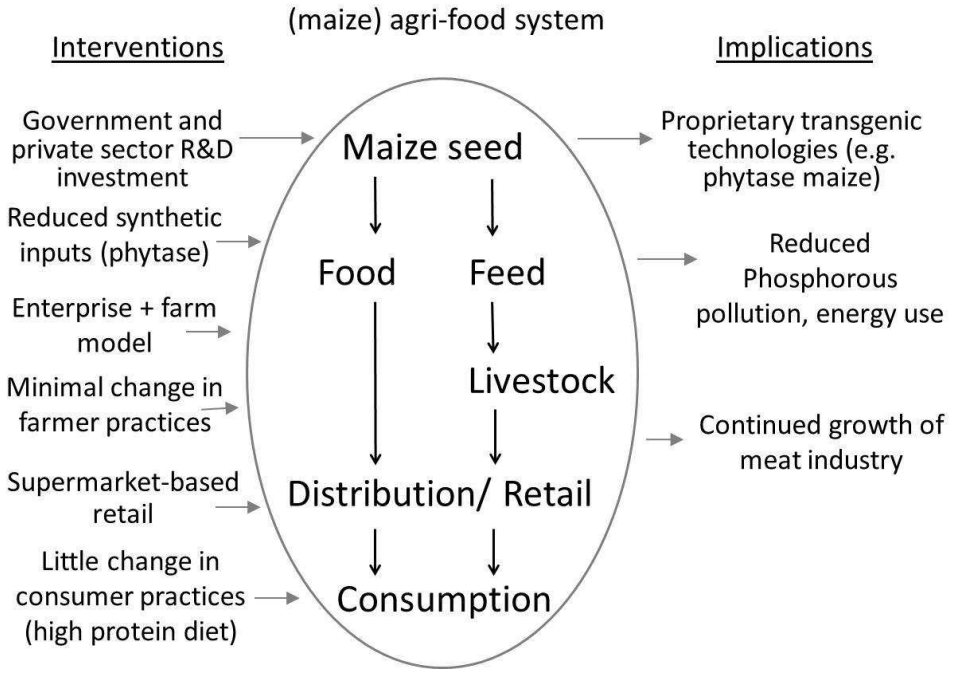

Figure 4. Diagrammatic representation of the 'indigenous innovation' pathway

3.2. Agro-ecological Approaches and Green Food Chains

Agro-ecological farming – as it is broadly defined by Silici (2014, 7-8) as "the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems" reduces the use of synthetic fertiliser and, as a direct result, the carbon intensity of production. Reduced pollution from nitrates and phosphates, and reduced food safety and environmental risks from synthetic pesticides, are additional benefits. In this vein, the post-1978 Reform Era has seen interest in upgrading low external input maize agriculture in China through conventional (including participatory) plant breeding, improved management practices and supply chain innovation towards high-quality products to serve wealthier urban and overseas markets (Paull 2007). This "alternative" pathway seeks to develop agricultural practices that are more sustainable and lower carbon, but stand in marked contrast to the high-tech, IP-intensive approach to

innovation that has characterised the development of phytase maize. They are designed for – and practiced by – farmers at much smaller scales than those possible with much of the intensive farming that characterises the pathway described in 3.1, and often sit within polyculture systems alongside the cultivation of other crops, and combined with other, diverse livelihood strategies. As such, the alternative pathway helps to onserve some of the cultural and biological diversity associated with small-scale maize farming, enhancing resilience to climatic change and providing a basis for local adaptation.

This pathway appears to offer the potential of low carbon, climate-resilient food security – supplying safe and nutritious food whilst also retaining control of agri-food systems (and their associated economic exchanges) at the community level. As such, through focusing on change at the farmer level, driven by changing patterns of consumer demand and food practices, agro-ecological approaches and green food chains appeal far more to the 'lifeworld' than to 'systemic' rationalities (Spaargaren *et al* 2012) and are framed by socio-cultural concerns and a continued role for (better informed and educated) smallholders in China's rural development.

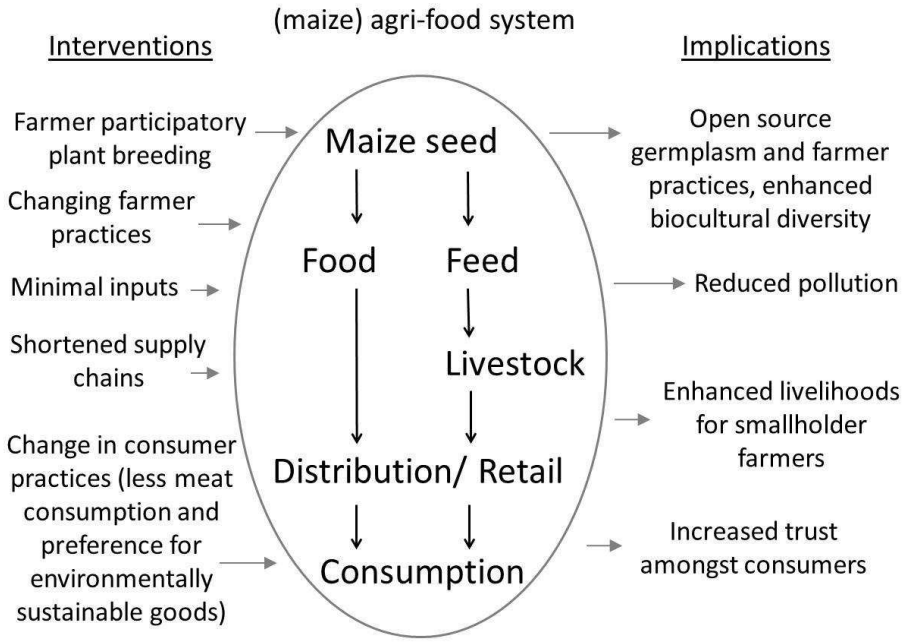

Figure 5. Diagrammatic representation of the 'alternative' pathway

4. Food practices relating to maize in China

Practices around phytase maize and agro-ecological farming are the culturally and socially embedded responses to developments and innovations of both "producers" and "users", including: arable farmers, buyers in the supply chain, organic or other certification schemes and other quality assurance practices; livestock-rearers feeding maize to their animals, including any preferences for particular forms of maize and

potential avoidance of non-organic due to particular beliefs or forms of market demand and quality assurance practices; food processors, using maize or maize-fed meat as ingredients, and their supply networks and quality assurance practices; and end consumers – of maize, meat or processed food, and their preferences for organic, green foods and other forms of certification. Just as Spaargaren *et al* identified the transition towards reflexive modernity and the primacy of the consumer in the practices and politics of food in OECD countries, an analogous process has unfolded in contemporary China, where consumer practices and agency – and a changing political landscape – have begun to reshape, or even overturn, the constitution of a top-down system of food production and distribution. In line with the theoretically and empirically informed approach described above, we focus in this paper on the practices of consumers.

In the 1980s, the "consumer" (*xiaofeizhe* 消费者) first arose as a feature of Chinese social life. The notion of "food safety" (*shipin anquan* 食品安全) emerged in China's media in the 1990s and only became a "household term" by the turn of this century (Yan 2012, 707). Today, public debates about food safety in China are "characterised by a sense of extreme anxiety and uncertainty" (FORHEAD 2014, 53-4). Surveys indicate 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" (FORHEAD 2014, 53).

These perceived food safety risks tend to relate to four categories of "deliberate contamination" (Yan 2012, 710): food adulteration, food additives, pesticides used as food preservatives and "fake foods", leading to a "rapid decline of social trust" (*Ibid*, 707). However, our research indicates that beyond decisions made in response to such direct safety risks, purchasing practices are also increasingly affected by buyers' evolving perspectives and framings of uncertainty, trust in regulatory systems (including around "organic" and "green" foods) and choices to be made around innovations (including genetically modified food crops). These "lifeworld rationalities" are increasingly felt by the market and shared in the public sphere, particularly the "green public sphere" (Calhoun and Yang 2007) that hosts an evolving discussion around sustainability questions. Media, particularly online and independent outlets, and NGOs can be seen playing an increasingly important role in Chinese public narratives around food, health and environmental issues (Geall 2012, 2013); in turn, the public narratives associated with particular pathways are central to the ways in which politics and practices are seen to emerge.

4.1. Consumer Practices around Phytase Maize and Links to Food Politics

State-run media in China, which as a mouthpiece for central government is typically a good indicator of dominant political narratives, initially praised phytase maize. In 2010, state news agency Xinhua (Zhang 2010) described it as "promising the low-carbon economic era". Another article in Xinhua headlined "Environmentally friendly maize and environmentally friendly pigs" described the potential benefits of the phytase maize pathway and concluded: "genetic modification is often demonised as an environmentally destructive technology, but as we can see, the clever use of genetic modification will help protect the environment" (Fang 2012). One study of two official newspapers, the

People's Daily and *Guangming Daily*, from 2002 to 2011, concluded that Chinese reporting of GM crops had emphasised the benefits of transgenic organisms and no articles had portrayed GM crops in a negative light (Du and Rachul 2012). Another, more recent study (Liu and Cong 2014) found some negative reports, but concluded that Chinese newspapers in different sectors mostly continue to represent GM crops in a positive light.

Underlying this dominant narrative were not only specific technological considerations but also deeper political dynamics. China's national policies, particularly those operationalized by the Ministry of Science and Technology (MOST) – which supports agricultural biotechnology as a strategic industry and administers R&D funding through the government's 863 programme –strongly emphasise the development of technological capabilities in transgenic science and technology, a focus that dates back to the 1980s, when China became one of the first countries to experiment with genetically modified crops. For example, China's 12th Five Year Plan (2011-2015) states that China will "speed up the innovation and application of biotechnology breeding in agriculture" and identified agricultural biotechnology as one of the seven "Strategic Emerging Industries" supported by subsidies, tax breaks and other preferential policies. Agricultural biotechnology is also one of the key components of the Medium-Long Term Plan for Science and Technology (2006-2020) and an area in which China's potential for indigenous innovation may at some point challenge incumbent leading US and European firms.

However, the political landscape for GM commercialization was called into question in August 2014, when China's Ministry of Agriculture (MOA) – which, by contrast with R&D-focused MOST, administers the granting of biosafety certificates for field trials, commercialisation or import of GM crops (the Ministry of Environmental Protection also has a small role in these issues, as the "focal point" for the Convention on Biological Diversity and Cartagena Protocol on Biosafety) – neither commercialised nor renewed the biosafety certificates for phytase maize. These five-year certificates for field trials were eventually granted again in January 2015, but in the intervening months, official justifications for this delay were notably absent. In August 2014, Wang Jing from Greenpeace China told a reporter: "We believe that loopholes in assessing and monitoring [GM] research, as well as the public concern around safety issues are the most important reasons that the certifications have not been renewed" (Normile 2014).

The public response from an environmental NGO activist here is notable, as it indicates the extent to which such non-governmental groups are increasingly perceived as part of a debate around regulating research and innovation. However, hers was not the only opinion. Others, such as scientist Huang Jikun, argued (for Bt rice, for which biosafety certificates were also not renewed) that as China has now reached self-sufficiency without GM varieties, there was less economic rationale to move towards commercialisation, but that the decision did not reflect a change in China's overall policy regarding agricultural biotechnology. Other industry insiders suggested that phytase maize had performed less than optimally in research trials (Interview with WJ 2014). Finally, some (Cong 2014) saw this as evidence of an elite distrust of GM technologies.

Our research could not ascertain a single, definitive reason for this delay. However, initial findings did indicate that it reflected emerging public perceptions and framings around which media and civil-society organisations seem to play a role. Furthermore, few believed the decision was one taken solely by the MOA; many believed such decisions were taken at higher political levels in response to social stability concerns. As such, these concerns seem to confirm Keeley's suggestion that the country's "embrace of the biotechnology revolution" is "not as unequivocal as much global discourse suggests" (Keeley 2005: 157), perhaps most significantly among end consumers. This often overlooked consumer dimension seems to have first emerged with debates around the Chinese-developed insect-resistant Bt63 rice, sparked by an investigative report in the influential, liberal Guangzhou-based newspaper *Southern Weekend* in 2004, which suggested scientists had attempted to commercialise the GM rice "for their personal commercial interests." More recently, a critical documentary made by state television host Cui Yongyuan, which was widely distributed online, aired concerns about the "controversy" around GM in "US academic circles" (Zhang 2013). Taken together, these debates have constituted what Jia and Liu (2014: 34) called the first case of the Chinese public questioning "science and the people doing science".

Consumer practices and associated concerns therefore seem closely related here to existing political concerns about the risk–regulatory framework, no doubt conditioned by the wider decline in social trust regarding food and its regulation (Yan 2012), but also perhaps by wider concerns around science and innovation governance and environmental regulation (apparent also in debates around waste incineration, the urban siting of petrochemical plants and nuclear power stations)(cf. Geall 2013). In 2004, the same year that the *Southern Weekend* article appeared, one Ipsos survey on GM foods in Beijing, Shanghai and Guangzhou, commissioned by Greenpeace, found that 57% of people surveyed were "against GM foods" and only 16% would eat GM foods (Zi 2010, 110).

Interviews indicated that some consumers feel they have been left out of an important decision, that uncertainties suggest the need for precaution with regard to health and that powerful pro-GM interests have distorted consumer choice. In a typical example, one young woman employed by an environmental NGO in Beijing, said:

> "Regarding GM, I am quite doubtful… I am not involved in the scientific decision, because I am not a scientist. But we don't have the right to choose" (Interview with BY 2014)

She went on to cite the potential impact on the wider environment when GM crops are "released into nature" and the lack of government "transparency" in the regulatory decisions that have been made around this pathway. Another interview indicated that health- and environment-focused consumers at Beijing Farmers Market (see below) were also increasingly asking farmers whether their feed was from GM sources (Interview with CT 2014). Scientists and NGO representatives expressed the opinion that the delay in granting certificates was due to public perceptions. Significantly, one woman from an environmental NGO (Interview with YH 2014) said that biosafety was "a hot topic" among scientists and consumers and that NGOs and media needed to use online

technologies to enrich a more objective and more transparent debate. Even private sector insiders who regarded the decision in primarily technical or economic terms (Interview with WJ 2014) saw public perceptions as a significant hurdle the Chinese government increasingly needs to take into account when approaching commercialization decisions.

4.2. Practices and Politics Around Organic and Agro-Ecological Maize

The same process of transition around the practices of food consumption in contemporary China has also had significant impacts on the development of maize agriculture within the overlapping sectors of "organic" (有机 *youji*) or "ecological" (*shengtai* 生态) food production and distribution (which we group together as agro-ecological production of maize under what we term the 'alternative' pathway). We provide some background to these sectors, before presenting findings on emerging practices and their political implications.

The early development of organic and agro-ecological farming standards in China enjoyed some state support – particularly from the MOA, which created the Green Food Development Centre in Beijing in the early 1990s, and the MEP, which alongside the MOA has helped to certify chemically reduced "green foods" (绿色食品 *lvse shipin*) and "organic" foods (Thiers 2002). However, government assistance for the development of organics and related pathways in China has been far smaller than its support for agricultural biotechnology and the indigenous innovation pathway. Stakeholder interviewees working in agro-ecological production and distribution, of maize and other crops, suggested that they and others had received no discernible support from government; in fact, one organic entrepreneur decried the fact that large, foreign-invested conventional farms could qualify for government subsidies, when they could not (Interview with CT 2014).There are also high levels of public and farmer distrust of the certification system around green and organic foods (Interview with LY 2014; Klein 2009).

Under the dominant "enterprise plus farmer" model for organic production, wholesalers contract production work out to individual farmers, supply inputs such as seeds and organic fertiliser, and reap most of the profits. However, this model is increasingly opposed by sustainability-oriented activists, farmers and intellectuals in China, particularly those associated with the New Rural Reconstruction Movement (NRRM), which emerged as a political force in the early 2000s to popularise alternative ideas of rural development. Such views are not a mainstream consensus in China, yet they enjoy some elite support and have had an impact on the government campaign to "Build a New Socialist Countryside" (Anagnost 2014) to reduce the "commodification of agricultural inputs, labour, public goods and technical services" and to reverse "the exodus of educated rural youth" to the cities that was brought by the post-1978 Reform Era (Yan and Chen 2013: 964).

At the same time as the urbanisation of rural villages, industrial consolidation and similar reforms have taken place, others have attempted to create new linkages between rural producers and urban consumers. In an effort to counter the increasing erosion of genetic

diversity in maize – where, in Guangxi province, 71% of the maize coverage currently relies on just 5 inbred lines (Song and Vernooy 2010) – the Farmers Seed Network, an alliance of researchers and agriculture-focused NGOs, has encouraged genetic diversity in maize crops in rural southwest China through seed saving and traditional forms of seed exchange. This is intended to increase resilience to biotic and abiotic (including climatic) shocks and stresses by supporting not only seed exchange and participatory plant breeding, but also new models of retail direct from small-scale producers of maize, for both food and feed, to "ecological" restaurants in the provincial capital Nanning. This has involved farmers and local organisations in a concerted effort to improve crop varieties and rural livelihoods, while addressing consumers' trust deficit and demands for safer food.

Sales of organic food direct to urban residents have particularly been promoted as a model by groups addressing a crisis of trust among consumers (Zhang et al forthcoming) by practicing new approaches including "Community Supported Agriculture" (CSA) in major cities, such as Beijing and Chengdu, promoted by groups such as the Hong Kong-based NGO Partnership for Community Development (PCD). Bishan Commune, in Anhui province in central China, founded by the artist Ou Ning, has not only become a centre for artistic and cultural events related to the NRRM (Walker 2013), but also has seen farmers selling organic produce directly to urban consumers via social media and e-commerce websites (Larson 2014), reminiscent of the move towards "short food-supply chains" in Europe (Oosterveer and Spaargaren 2012).

While it seems that many such urban consumers are concerned foremost about the safety of the foods they buy, and to some extent about the wider environmental impact, it is notable that CSA advocates point out the wider political critique at work in such alternative models. For participants in CSA, writes one advocate (Yin 2012), "'organic' isn't about certification, but the trust, support and sharing involved in simple business transactions," before going on to cite the charismatic Hebei farmer An Jinlei: "As a farmer, I don't like the term 'organic'. It's become a buzzword and lost its meaning. The rich folk in the city drive their cars to the supermarket and buy organic food – they're just worried about their own health. But what are their lifestyles and values, their excessive consumption of resources, doing to the health of the planet?"

Such changing perceptions, closely related to a political critique around rural development, seem also to have affected consumer practice and agency. Garnett and Wilkes (2014: 95) cite two international comparative surveys that found "the environmental motivations of Chinese consumers are quite high", with one finding that "44% of Chinese respondents said they were willing to pay more for products that are good for the environment, a greater percentage than in the US or UK" and the other that food based on "agricultural systems that use fewer or no chemical inputs, such as those based on 'green' or organic approaches" was "seen as safer than those which may rely very heavily on such inputs." While Klein (2009, 77) wrote there is little in the way of "organised promotion of ethically motivated consumption" in China, a number of evolving initiatives and other social phenomena suggest the emergence of changing perspectives – if not full-scale changes of practice – that may support the alternative

pathway for agri-food systems.

Initial findings from our research suggest that some Chinese consumers and farmers of maize, as well as small firms involved in retail and distribution, in the absence of significant state support for organic and agro-ecological approaches, have nevertheless addressed the proliferation of complex and uncertain problems and risks around food, agriculture and the environment in an innovative and sophisticated fashion. New types of "bottom-up" innovation (Tyfield et al forthcoming) in response to sustainability challenges have included: the establishment of new networks, enabled by digital technologies, which connect (typically non-certified) organic and "ecological" farmers to consumers, to benefit small, local producers while increasing trust and knowledge about sustainable agricultural practices; journalists and activists helping consumers to share information about food-safety risks, through online platforms such as *Zhichuchuangwai* (掷出窗外 "Throw it out of the window") (Wu and Han 2012); and small, rural farming cooperatives, such as Little Donkey Farm outside Beijing, mushrooming across China, typically practicing forms of organic or ecological agriculture (Yan and Chen 2013). As such, the practices implied by the 'alternative' pathway appeal very much to the 'lifeworld rationalities' (Spaargaren et al 2012) not only of consumers, but also of China's smallholder and peri-urban farmers.

One activist/entrepreneur from Beijing Farmers Market, a retail experiment for smallholder farmers growing organic produce, said that she had witnessed a changing consumer attitude in the past few years. While at first its predominantly young and professional consumers "came for safe food" in response to health concerns, through communication on social media, she had helped to introduce consumers to the "social justice mission" of the project: "why there are problems with the food system and how we can change it". She added that consumers, who are kept informed about farmers' practices through online, mobile messaging services, "know the price is fair and they know the producers quite well and like the feeling of connection." Most of the farmers themselves use social media service Weibo and "communicate with consumers on a daily basis" (Interview with CT, 2014). The evidence suggests that – beyond the challenges of food and environmental safety, the 'alternative' pathway aligns much more easily with concerns of community cohesion and social justice, which have also been implicated in changing practices in Europe (Spaargaren et al 2012).

In conclusion, much as environmental media, NGO campaigns, consumer activism and other forms of public participation by civil society have attempted to increase environmental awareness and improve local enforcement of environmental regulations over the past decade (Geall 2013), concerns have also increased about environment and health issues related to the consumption of crops, including maize, particularly (though not exclusively) among China's newly enriched middle class, with opinions expressed more freely and rapidly than ever before due to increasingly ubiquitous social media and messaging technologies. Furthermore, just as China has seen an overall trend towards higher consumption of meat, the past decade has also seen the "rapid development" of vegetarian, organic and ecological catering in Chinese cities for example, the emergence of a "new vegetarianism" among the "young, urban elite": a "holistic response to a nexus

of concerns about human health, the environment, animal welfare and the wastefulness of feeding grains to animals" (Garnett and Wilkes 2014: 96). This resonates with the emergence of new consumer agency and practices, evident from our research findings, which might prove a driver for alternative pathways for the maize agri-food system in China.

5. Discussion

This paper has adopted a "food practices in transition" approach (Spaargaren et al 2012), drawing on other concepts from the transitions and pathways (Leach et al 2010) literature to understand the role of consumer practices in low carbon and sustainable food systems. In particular, we found that consumption practices associated with the 'indigenous innovation' (transgenic) and 'alternative' (agro-ecological) pathways of changing maize production and consumption were associated with very different rationalities, and – to greater or less extent – aligned with the prevailing preferences of top-down policy support. This leads us offer original insights into the role of practices, and their links to food governance and politics, in China's potential transitions towards more sustainable production and consumption systems.

We found that the two pathways studied here envisage (and are rooted in) very different potential futures for China's food systems and involve different, sometimes conflicting, social constituencies, political actors, institutions and discourses. From the 'system rationality' perspective of policymakers and scientists, innovation in Chinese agriculture has principally occurred in seeds, fertilisers (and other inputs) and livestock technologies. Whilst in theory these may contribute to lessening the biophysical impacts of modern Chinese agriculture (in terms of greenhouse gas emissions and environmental pollution), we found that practices – both of farmers and consumers – were left neglected by such a vision. The place of rural smallholders in the 'indigenous innovation' pathway is questionable, and the opportunities for better practices (in terms of rational use of fertilizer, for example) are disregarded. The practices of consumers, who are gradually raising expectations of food safety and environmental sustainability against the background of rising distrust in food supplies, preclude the early commercialization of transgenic maize and have contributed to delays in the country's most advanced transgenic feed product.

At the same time, our research indicates that there are other forms of innovation in Chinese agri-food systems, many emerging in response to consumers' changing preferences, including efforts such as "green food" labeling schemes, agro-ecological food delivery projects and novel retail approaches, community-supported farms or social movements around vegetarianism and other dietary practices. In focusing on consumer practices, opinions, beliefs and wider socio-cultural frames, we point to an under-appreciated and under-researched component of the Chinese agri-food system. In addition, we begin to describe the political aspects of these pathways, pointing to the links between consumer practices, the role of the media and the emerging green public sphere in China.

In conclusion, this article has outlined the systemic nature of these two pathways and provided evidence that they are intrinsically bound to political debates about the future of Chinese agriculture and innovation. These futures sometimes take for granted changes of practice that our evidence suggests may not be possible or widely supported. These insights raise important questions for future studies of China's transition to more sustainable forms of production and consumption, not only in maize, but across and even potentially beyond the agri-food sector. More detailed analyses of the links between media, social networks and the ways they interact with socio-cultural framings of sustainability and associated practices are required not only to better-understand emerging transition processes, but also to better-inform the raft of Chinese policies that are transforming relationships between the country's rural and urban residents, and the wider human-environment relationship. This paper a significant step toward more detailed studies of this kind that take politics and practice seriously in investigating transition pathways for China – research that is relevant not only for China but, in the context of a warming, rapidly urbanizing world, for the wider international community.

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References

Abramovitz, M. (1986) 'Catching up, forging ahead, and falling behind', *Journal of Economic History* XLVI.2: 385-406

Altenburg, T., H. Schmitz and A. Stamm (2008) 'Breakthrough China's and India's Transition from Production to Innovation', *World Development* 36(2): 325-344

Anagnost, A. (2014) 'A New Great Leap Forward? China's Urbanization: Implications for Food Security and Rural Well Being' Paper presented to Conference on Urbanization and Development in China, University of Southampton.

Burney, J.A., S.J. Davis & D.B. Lobell (2010) 'Greenhouse gas emission by agricultural intensification', *Proceedings of the National Academy of Sciences* 107(26): 12052-57.

Businesswire (2009) 'Origin Agritech Limited Reaches Agreement for Novel Glyphosate-Tolerance Gene, Worldwide Rights for Genetically Modified (GM) Corn, Soybean, Rice, Cotton, and Canola products', http://www.businesswire.com/news/home/20090917005626/en/Origin-Agritech-Limited-Reaches-Agreement-Glyphosate-Tolerance-Gene, (accessed 29 November, 2013)

Byrne, R., Smith, A., Watson, J. and Ockwell, D. (2011) 'Energy Pathways in Low-Carbon Development: From Technology Transfer to Socio-Technical Transformation', STEPS Working Paper 46, Brighton: STEPS Centre

Calhoun C, Yang G. (2007) 'Media, civil society, and the rise of a green public sphere in China.' *China Information* 21:211-236

China Water Risk (2013) '2012 State of Environment Report Review,' http://chinawaterrisk.org/resources/analysis-reviews/2012-state-of-environment-report-review/ (18 December, 2013)

Cong, C. (2014) "China's fight to feed itself is hindered by anti-GM paranoia" *The Conversation*, August 18. Available at: https://theconversation.com/chinas-fight-to-feed-itself-is-hindered-by-anti-gm-paranoia-30586 (accessed November 14, 2014).

Du, L. and Rachul, C. (2012) 'Chinese newspaper coverage of genetically modified organisms' *BMC Public Health* 12:326

Ely, A. and Scoones, I. (2009) 'The Global Redistribution of Innovation: Lessons from China and India', STEPS Working Paper 22. Brighton: STEPS Centre.

Elzen, B., F. W. Geels and K. Green (Eds) (2004). System Innovation and the Transition to Sustainability: Theory, Evidence and Policy, Cheltenham: Edward Elgar.

Fang, Z. (2012) '*Fang Zhouzi: Huanjing yumi yu huanjing zhu*方舟子:环保玉米与环保猪 [Fang Zhouzi: Environmentally friendly maize and environmentally friendly pigs]' *Xinhua Ribao Dianxun* 20 April

FAO (2012) http://faostat3.fao.org/ FAOSTAT maize production data/ China mainland, (accessed July 28, 2015)

FAO (2013) http://faostat3.fao.org/ FAOSTAT pork and chicken data/ China mainland, (accessed July 28, 2015)

FORHEAD – Forum on Health Environment and Development (2014) 'Food Safety in China: a Mapping of Problems, Governance and Research' Working Group on Food Safety

Freeman, C. (1996) 'The greening of technology and models of innovation.' *Technological Forecasting and Social Change* 53(1): 27-39

GAIN (Global Agricultural Information Network) Report (2009) China – People's Republic of, Biotechnology, GAIN Report Number:CH9091, http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biotechnology_Beijing_China%20-%20Peoples%20Republic%20of_11-25-2009.pdf (accessed September 29, 2014)

Garnett, T. and Wilkes, A. (2014) '*Appetite for Change: social, economic and environmental transformations in China's food system'*, Food Climate Research Network, University of Oxford.

Geall, S. (Ed)(2013) China and the Environment: the Green Revolution, London: Zed Books

Geall, S. (2012) 'Media Coverage of the Environment', in: S. Geall *et al* (eds) *Berkshire Encyclopedia of Sustainability: China, India, and East and Southeast Asia: Assessing Sustainability* Great Barrington, MA: Berkshire Publishing

Geels, F. (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, *Research Policy* 31, 1257–1274

Geels, F. and Schot, J. (2007) Typology of sociotechnical transition pathways, *Research Policy* 36, 399–417

Ho, P., E. B. Vermeer, & J. H. Zhao (2006) Biotechnology and Food Safety in China: Consumers' Acceptance or Resistance? *Development and Change* 37(1): 227-254

Hu, D., T. Reardon, S. Rozelle, P. Timmer and H. Wang (2004) 'The Emergence of Supermarkets with Chinese Characteristics: Challenges and Opportunities for China's Agricultural Development' *Development Policy Review* 22 (5): 557-586.

Huang, J. H. Qiu, J. Bai & C. Pray (2006) Awareness, acceptance of and willingness to buy genetically modified foods in Urban China, *Appetite* 46: 144-151

Interview (semi-structured) with BY, a domestic Chinese environmental NGO representative, conducted September 30, 2014, in Beijing.

Interview (semi-structured) with CT, a social entrepreneur working with organic and ecological farmers, conducted September 22, 2014, in Beijing.

Interview (semi-structured) with WJ, a private sector worker in agricultural biotechnology, conducted September 25, 2014, in Beijing.

Interview (semi-structured) with YH, a domestic Chinese environmental NGO (Yunnan province) representative, conducted September 25, 2014, in Beijing.

Interview (semi-structured) with LY, a Chinese academic working with farmers and consumers, conducted September 24, 2014, in Beijing.

IPCC (2014) Summary for Policymakers, in Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the

Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jia, H. and Liu, L. (2014) 'Unbalanced progress: The hard road from science popularisation to public engagement with science in China', *Public Understanding of Science* 23(1):32-7

Keeley, J. (2005) 'Interrogating China's Biotech Revolution: Contesting dominant science policy cultures in the risk society' in: M. Leach, I. Scoones and B. Wynne *Science and citizens: globalization and the challenge of engagement,* London: Zed Books

Kern, F. (2011)' Ideas, institutions, and interests: explaining policy divergence in fostering `system innovations' towards Sustainability' *Environment and Planning C: Government and Policy* 29:1116 -1134

Klein, J. (2009) 'Creating ethical food consumers? Promoting organic foods in urban Southwest China' *Social Anthropology* 17(1):74-89

Larson, C. (2014) 'E-Commerce Gives a Lift to China's Rural Farmers' *Bloomberg Businessweek* 13 February

Leach, M., I. Scoones and A. Stirling (2007) 'Pathways to Sustainability: an overview of the STEPS Centre approach' Brighton: STEPS Centre.

Leach, M., I. Scoones and A. Stirling (2010) 'Dynamic sustainabilities: Technology, Environment, Social Justice' London: EarthScan

Leach, M., J. Rockström, P. Raskin, I. Scoones, A. Stirling, A. Smith, J. Thompson, E. Millstone, A. Ely, E. Arond, C. Folke, P. Olsson (2012) 'Transforming Innovation for Sustainability' *Ecology and Society* 17(2):11

Lema, R. and Lema, A. (2012) 'Technology transfer? The rise of China and India in green technology sectors', *Innovation and Development* 2(1): 23-44

Li, J., E. Lammerts van Bueren, J. Jiggins, and C. Leeuwis (2011) 'Farmers' adoption of maize (Zea mays L.) hybrids and the persistence of landraces in Southwest China: implications for policy and breeding', *Genetic Resources and Crop Evolution* [online]

Liu, Y. and Cong, C. (2014) "Newspaper coverage of genetically modified foods in China" *Proceedings of the Science and Technology Indicators Conference 2014 Leiden* pp.380-2

Lockwood, M. (2013) 'Governance, Innovation and the Transition to a Sustainable Energy System: Perspectives from Economic Theory' EPG Working Paper: 1305

Ma, D. and Adams, W. (2013) *In Line Behind a Billion People; Will Scarcity Stop China from Winning the Global Economic Race?* Pearson Education

Mazzucato, M. (2013) *The Entrepreneurial State: debunking public vs. private sector myths*, London: Anthem Press

Meadowcroft, J. (2009). "What about the politics? Sustainable development, transition management, and long term energy transitions." Policy Sciences 42(4): 323-340

MEP - Ministry of Environmental Protection (2013) *State of Environment Report 2012* [Chinese] Available at: http://www.mep.gov.cn/gkml/hbb/qt/201306/W020130604382172090857.pdf (Accessed 18 December 18, 2013)

Normile, D. (2014) China pulls plug on genetically modified rice and corn, *Science Insider* August 20 Available at: http://news.sciencemag.org/asiapacific/2014/08/china-pulls-plug-genetically-modified-rice-and-corn (Accessed August 28, 2014)

Oosterveer, P. and Spaargaren, G. (2012) Green Consumption Practices and Emerging Sustainable Food Regimes: The Role of Consumers, Chapter 6 in Spaargaren, G., Oosterveer, P. and Loeber, A. (Eds) Food practices in transition: changing food consumption, retail and production in an age of reflexive modernity, Abingdon: Routledge

Oosterveer, P. (2012), Restructuring Food Supply: Sustainability and Supermarkets Chapter 7 in Spaargaren, G., Oosterveer, P. and Loeber, A. (Eds) Food practices in transition: changing food consumption, retail and production in an age of reflexive modernity, Abingdon: Routledge

Origin Agritech (2008) 'GM Phytase Corn Saves Feed Costs and Improves the Environment' http://gmopundit.blogspot.co.uk/2008/02/gm-phytase-corn-saves-feed-costs-and.html (accessed 18 December, 2013)

Origin Agritech (2013) 'Origin Agritech Limited Reports Unaudited Financial Results for the Year Ended September 30, 2012,' http://www.marketwatch.com/story/origin-agritech-limited-reports-unaudited-financial-results-for-the-year-ended-september-30-2012-2013-01-08 (accessed 18 December, 2013)

Paull, J. (2007) 'China's organic revolution', *Journal of Organic Systems* 2(1):1-11

Porter, M. E. and C. van der Linde (1995) 'Toward a New Conception of the Environment-Competitiveness Relationship' *The Journal of Economic Perspectives* 9(4):97-118

Qiu, J. (2010) 'Phosphate fertiliser warning for China,' *Nature* 29 September

Reardon, T., Berdegué, J. and Timmer, P. (2005) 'Supermarketization of the "Emerging Markets" of the Pacific Rim: Development and Trade Implications' *Journal of Food Distribution Research* 36(1).

Rennings, K. (2000) 'Redefining innovation - eco-innovation research and the contribution from ecological economics' *Ecological Economics* 32(2):319-332

Rip, A. and R. Kemp (1998) 'Technological Change' in S. Rayner and E. L. Malone (Eds) Human choice and climate change, Columbus OH: Battelle Press

Rockström, J. *et al.* (2009) 'A safe operating space for humanity.' *Nature* 461(7263): 472-475

SAIN (2011a) UK-China Project on "Improved Nutrient Management in Agriculture – a Key Contribution to the Low Carbon Economy", UK-China Sustainable Agriculture Innovation Network, http://www.sainonline.org/SAIN-website(English)/pages/Projects/lowcarbon.html

SAIN (2011b) Improved Nutrient Management in Agriculture – A Neglected Opportunity for China's Low Carbon Growth Path, Policy Brief No. 1, Sustainable Agricultural Innovation Network, http://www.eu-china.net/upload/pdf/materialien/11-02-11_PolicyBriefNo1updatedfinal.pdf, accessed 29/7/2015

Schmitz, H. (2013) 'How does the global power shift affect the low carbon transformation?' Brighton: Institute of Development Studies

SciDev.net (2009) 'China makes 'landmark' GM crop approval', Available at: http://www.scidev.net/global/biotechnology/news/china-makes-landmark-gm-food-crop-approval.html, (Accessed 29 November, 2013)

Schneider, M. and S. Sharma (2014) 'China's Pork Miracle?Agribusiness and Development in China's Pork Industry' Institute for Agriculture and Trade Policy

Seyfang, G. and A. Smith (2007) "Grassroots innovations for sustainable development: towards a new research and policy agenda" *Environmental Politics* 16(4): 584-603

Shove, E. and B. Walker (2007) "CAUTION! Transitions ahead: Politics, practice and sustainable transition management" *Environment and Planning A* 39(4): 763-770

Shove, E. and Walker, G. (2010) 'Governing transitions in the sustainability of everyday life' *Research Policy* 39(4):471-476

Smith, A. (2006) Green niches in sustainable development: the case of organic food in the United Kingdom, *Environment and Planning C: Government and Policy* 24: 439-458

Smith, A., F. Kern, R. Raven and B. Verhees (2014) 'Spaces for sustainable innovation: Solar photovoltaic electricity in the UK' *Technological Forecasting and Social Change* 81: 115-130

Smith, L. E. D. and Siciliano, G. (2015) A comprehensive review of constraints to improved management of fertilizers in China and mitigation of diffuse water pollution from agriculture, *Agriculture, Ecosystems & Environment* 209:1, 15–25

Song, Y. & Vernooy, R. (2010) Seeds and synergies: innovating rural development in China. Rugby and Ottawa: Practical Action Publishing and IDRC

Southerton, D., Díaz-Méndez, C. and Warde, A. (2011) 'Behavioural Change and the Temporal Ordering of Eating Practices: A UK–Spain Comparison' *International Journal of Sociology of Agriculture and Food* 19(1):19-36

Spaargaren, G. (2011) Theories of practices: Agency, technology, and culture: Exploring the relevance of practice theories for the governance of sustainable consumption practices in the new world-order, *Global Environmental Change* 21, 813-822

Spaargaren, G., Oosterveer, P. and Loeber, A. (Eds) (2012) Food practices in transition: changing food consumption, retail and production in an age of reflexive modernity, Abingdon: Routledge

Steffen, W., K. Richardson, J. Rockström, S. E. Cornell, I. Fetzer, E. M. Bennett , R. Biggs, S. R. Carpenter, W. de Vries, C. A. de Wit, C. Folke, D. Gerten, J. Heinke, G. M. Mace, L. M. Persson, V. Ramanathan, B. Reyers and S. Sörlin (2015). "Planetary boundaries: Guiding human development on a changing planet." Science 347(6223)

Thiers, P. (2002) 'From grassroots movement to state-coordinated market strategy: the transformation of organic agriculture in China', *Environment and Planning C: Government and Policy* 20:357-373

Tyfield, D, A. Ely and S. Geall (forthcoming) "Low Carbon Innovation in China: The Opportunities and Challenges of Transition in Power Relations and Practices" *Sustainable Development* special issue on 'Environmental Innovation, Development & Emerging Economies'

Verhees, B., R. Raven, F. Veraart, A. Smith and F. Kern (2013) 'The development of solar PV in the Netherlands: A case of survival in unfriendly contexts' *Renewable and Sustainable Energy Reviews* 19: 275-289

Walker, B. (2013) 'Stemming the tide of urban-rural migration' *chinadialogue* 22 August https://www.chinadialogue.net/books/6312-Stemming-the-tide-of-rural-urban-migration/en

Yan, Y. (2012) 'Food Safety and Social Risk in Contemporary China', *The Journal of Asian Studies* 71(3):705-729

Yan, H. and Chen, Y. (2013) 'Debating the rural cooperative movement in China, the past and the present', *The Journal of Peasant Studies* 40(6):955-981

Yin, C. (2012) 'We're all farmers now', *chinadialogue* 29 May https://www.chinadialogue.net/article/show/single/en/4944-We-re-all-farmers-now

Zhang, S., Huang, K. and Song, Y. (2010) 'Maize and the formal agricultural research and development system: evolution, challenges, and alternatives' in *Seeds and Synergies: Innovation in Rural Development in China*, Song, Y and Vernooy, R., (eds) Rugby and Ottawa: Practical Action Publishing and IDRC

Zhang, C. (2010) '*Zhuanjiyin zhisuanmei yumi zai ditanjingjishidai dayoukewei* 转基因植酸酶玉米在低碳经济时代大有可为 [GM phytase maize has bright prospects in the low-carbon economic era]' *People's Daily* 18 March

Zhang, L,. Xu, Y., Oosterveer P. and Mol, A. P. J. (forthcoming) Consumer trust in different food provisioning schemes: evidence from Beijing, China, *Journal of Cleaner Production* (under review)

Zhang, W., Z. Dou, P. He, X. Ju, D. Powlson, D. Chadwick, D. Norse, Y. Lu, Y. Zhang, L. Wu, X. Chen, K. G. Cassman and F. Zhang (2013) 'New technologies reduce greenhouse-gas emissions from nitrogenous fertilizer in China' *Proceedings of the National Academy of Sciences* 13 May

Zhang, Y. (2013) 'Celebrity feud ramps up GM food debate' *Global Times* 26 December

Zi, Y. (2010) 'Opportunities and risks of genetically modified crops' in: Yang, D. (ed) *The China Environment Yearbook, Volume 4: Tragedy and Hope*, Leiden: Brill