FOOD AND THE SOCIOGENESIS OF CLIMATE CHANGE: HOW OPPOSITES ATTRACT, THE TRAJECTORIES OF CHINA AND BRAZIL.

Abstract

It is widely recognised that changing and growing demand for food, including the transition to eating more meat, is a major source of greenhouse gases inducing climate change. This paper develops a concept of the sociogenesis of climate change to analyse the interactions between particular political economies and their natural resource environments (land, water, sun), focusing on the production and consumption of food. The approach is both comparative and historical, taking the cases of China and Brazil. Their developmental trajectories are contrasted in both their generation and subsequent regulation of greenhouse gas emissions from agriculture. The analysis concentrates on some key dimensions: changing patterns of land holdings; different agronomies related to land-holding such as scale and mono-cropping; policies of food security and self-sufficiency; food export-orientation; and, last, but by no means least, cultural differences and transformations of societal norms of consumption. The paper concludes by drawing out some of the policy implications, both intra- and inter-national, for climate change mitigation.

Keywords

Climate change; Sociogenesis; Finite resource environments; Meat transitions; Environmental regulation; Brazil. China.

Introduction

The minting and expanding circulation of the concept of ‘the anthropocene’ (Crutzen and Stormer, 2000; Steffen et al. 2011; Ruddiman et al. 2015) has emphasised the role of human activity in constituting a new planetary epoch. It has been combined with concepts on the limits to growth and the crossing of planetary boundaries inducing irreversible and potentially catastrophic climate change (Rockström, 2009; Castree, 2015). Some critics from a social science perspective have sought to go beyond an amorphously global account of human activity, retaining the significance of impacts on the earth's atmosphere, but insisting on a more socially defined dynamic, with concepts such as the capitalocene (Moore, 2016) or sociocene (Ribot, 2014). These approaches suggest that the particular dynamics of capitalism as a world systemic society-nature relationship are developing an indissolubly combined economico-ecological crisis, perhaps equally as terminal for capitalism as for a planet inhabitable by humans and other biological species (Moore, 2010, 2011; Naess and Price, 2016).

This paper aims to develop a social science perspective by focussing on the production, distribution and consumption of food and its significance for climate change (Tian et al. 2016). As against an amorphously global or capitalism-in-general approach, it proposes a concept of the sociogenesis of climate change to denote the interactions between particular political economies and their natural resource environments (land, water, sun). The cases of Brazil and China, and the development of food trade between them, are taken as exemplifying contrasting developmental trajectories of such interactions, with significant differences in both their generation and regulation of greenhouse gas emissions from agriculture.[1]

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[1] The research was funded by an ESRC Professorial Fellowship 'The food-energy-climate change trilemma: developing a neo-Polanyian approach' ES/K010530/1. The research fieldwork included a wide range of interviews with experts, major food producers and traders, NGOs, and government officials, in both Brazil and China.

It is widely recognised that changing and growing demand for food, including the transition to eating more meat, is a major source of GHG inducing climate change, with growing and increasingly urbanised populations (Lu et al. 2015; McAlpine et al. 2009). Nonetheless, an examination of the NDCs (National Determined Contributions) presenting government policies to mitigate climate change at the COP21 2016 meeting in Paris suggests a widespread reluctance for nation states to fully address the climate change risks of food and agriculture. This paper seeks to make a contribution to the understanding of the different societal dynamics and hence policy implications involved in the nature of these risks and their potential mitigation.

The theoretical perspective informing this analysis is a neo-Polanyian one, which examines how different economies, in this case of food, are instituted in space and time, on the one hand, and how the way these economies interact with their natural resource environments change over time, on the other (Harvey, 2014; Harvey and Pilgrim, 2011). The approach is therefore both comparative and historical. A key dimension to this analysis concerns the finitudes of a given society's environmental resources. In the case of food, availability of agricultural quality land, ground and surface water, and sun are the key finitudes of concern. As will be seen, however, environmental resources available to an economy, although naturally 'given', may also be politically defined. So, for example, land use change in the Amazon biome may be restricted from deforestation, or in China the area of agricultural land may be protected from reduction by industrial, commercial, housing or other non-agricultural uses.

In this paper, the analysis of societal interactions with finite resource environments concentrates on some key dimensions: the changing patterns of land holdings, their ownership and control; different agronomies related to land-holding such as scale and mono-cropping; policies of food security and self-sufficiency; food export-orientation; and, last, but by no means least, cultural differences and transformations of societal norms of consumption. The politics of food are at play across all of these dimensions, and, to that extent, the analysis is of 'politically instituted' economies of food.

The climate change consequences of these instituted economies of food, situated in their different ecologies, are also diverse across some key dimensions. Land-use change, where and how it happens, is of immense significance. Different agronomies related to land-use and land use change, how and where what meat (beef, pork, poultry) are produced, intensive use of nitrogen phosphate fertilizers including for rice, all have contrasting levels of GHG generation, from CO_2, as well as nitrous oxide (N_20), and methane (CH_4). Whether a society's culture is predominantly beef-, poultry-, pork-eating – or indeed vegetarian – has major climate change consequences.

Finitudes of environmental resources, instituted economies of food production and consumption, and agronomic GHG generation together constitute the sociogenesis of climate change. Different societal dynamics generate distinctive climate change impacts. The fact that different societies exhibit different dynamics has critical policy implications for the innovation of different, societally relevant, regulatory responses for climate change mitigation, which we reflect on in the conclusion.

In order to substantiate the argument for sociogenesis of climate change, the paper is constructed as follows. In schematised form, the developmental trajectories of China and Brazil, with their resource environments, key dimensions of societal interactions and their economies of food production and consumption, and the consequential GHG signatures are examined, then summarised in tabular form. These national trajectories then critically intersect from the early 21st century, with Brazilian exports to China developing a novel and significant reconfiguration of their respective economies of food. This leads us to question the appropriate unit of analysis for understanding the societal dynamics of climate change, arguing that neither producer country nor consumer country, but the new producer-consumer configuration is the appropriate spatial scale. We conclude by drawing out some of the policy implications, both intra- and inter-national, for climate change mitigation.

The Chinese sociogenetic trajectory

With a population of 1.35 billion, in spite of a relatively large land mass, China has one of the lowest per capita amounts of agricultural land in the world, at 0.08 hectares (World Bank, 2014a). Deserts, high altitude plateaus, mountainous areas mean that cultivatable land is concentrated along the Pacific shores and in the South and especially South East of the country. Moreover, much of its land is naturally poor in organic content, a tenth that of the UK, making its potential yield significantly lower than that attainable in more nutrient rich soils (Interview, Fusuo Zhang, May 2014). Its water resources available for agricultural production are even scarcer, at a quarter the world average, a fifth of that of the USA, and one fifteenth of Brazil (World Bank, 2014b). Again, its water resources are very unevenly distributed, with the North East being water poor compared with the South and South East (Lu et al. 2015).

If these are the 'naturally given' finitudes for Chinese agriculture, they were thoroughly modified by the agricultural regimes instituted by pre- and post-revolutionary China. Here, we focus on the key dimensions of landownership and food and agriculture policy, particularly self-sufficiency and food security. Since 1949, successive changes in landownership were uniquely and distinctively politically driven (Kerkvliet and Selden, 1998; Ye, 2015). These transformations describe a remarkable spiral, each radical reform echoing a previous phase of land-holding even in its novelty:

individualisation (type 1, 1949) - 3-stage collectivisation (types 1, 1953-78) – re-individualisation (type 2, 1978-1989) – re-collectivisation (type 2, 1997-). Following the Revolution, 300 million peasants were given full private property rights to the land they tilled, resulting in extreme fragmentation of land, but addressing the pre-revolutionary concentration of landownership by landlords and rich peasants. Enduring rural poverty and lack of development then led to three stages of progressive collectivisation, from mutual aid teams and low level cooperatives (1953-56), to cooperative-collectivisation (1956-8), finally to People's Communes (1958-78). In the short cooperative-collectivisation period, private landownership was replaced by full property rights of the collective, further expanded in scale with public ownership of land under the People's Communes. During these later phases, major transformations in agricultural infrastructure were developed in irrigation, roads, mechanisation, and seed provision. Following the turmoil of the Cultural Revolution, the major post-Mao Tse Tung reform re-instated individualised household farms under the Household Responsibility System, with the major difference that the local state retained ownership of the land. Households became leaseholders under leases initially of 15 years, then gradually extending, reaching a maximum of 70 years for certain types of farming. This has again resulted in extreme fragmentation, with typical landholdings of less than one third of a hectare. These changes in landownership have critical consequences for climate change, shaping the society's interactions with the environment in the production of food.

Egalitarian land distribution combined with incentives and subsidies directed at increasing production for the market, typifies the hybrid economic forms of market socialism. But, once more, the scale limitations of 230 million farms have triggered a process of re-collectivisation from the late 1990s, notably with Farmer Professional Cooperatives. In sharp contrast to the earlier collectivisation phase, this has been achieved by opening up of markets for land leases, where the peasant household rents out their leases to third parties, while the state continues to own the freehold. In Polanyian terms, this exemplifies a 'politically instituted market', where what can be traded and by whom, is prescribed by the central state (Guo et al., 2007; Zhang and Donaldson, 2008; Huang et al. 2012). These new forms of co-operative, moreover, have been complemented by a form of agricultural capitalist enterprise, the Dragon Head Enterprise, again a politically constructed entity, mostly involved in upstream agricultural activities of processing and distribution, but also in intensive livestock rearing (Schneider, 2016). The recent phases in landownership transformation have always been combined with a uniquely Chinese mode of socially engineering the rural-urban migration under the *hukou* registration system, with the urban population exceeding the rural in the second decade of this century (Mu and Giles, 2014). A significant number of peasants, now urbanised, complement their insecure and volatile urban incomes with rents from their traded land-leases (Ye, interview, 2016). Yet, however 'planned', a major consequence of these land reforms and migration controls has been an ageing and feminizing of the 'left-behind' rural population (Ye, et al. 2013). This presents a major challenge to the dominant current policy of modernisation, scaling-up and professionalization of agriculture.

These major transformations of the organisation of landownership were significantly driven by a dominant food policy of food security which, until joining the WTO in 2001, was equated with food self-sufficiency. The drive to feed the growing Chinese population was a paramount political imperative, particularly following the traumatic famines of the past. Alongside the reforms of the Household Responsibility System, therefore, policies were introduced to increase yields. Environmentally, the most significant of these were the industrial strategy to develop China's own nitrogen phosphate industry, on the one hand, and subsidies for farmers to purchase and use chemical fertilizers, on the other. While remarkably successful in raising Chinese agricultural productivity until recently (van der Plaug and Ye, 2016), these policies have led to an environmental catastrophe, undermining the prospect of both increasing yields and absolute agricultural outputs in key crops (Norse and Ju, 2015; Lu et al. 2015; Zhang, W.F. et al. 2013; Zhang, X., et al. 2014). As Fusuo Zhang put it: 'A farmer just buys a bag of fertilizer and dumps it on the land, making sure that there's enough by dumping too much.' (Interview, May, 2014; Liu et al. 2013) The quantity of fertilizer per hectare in China is now many times that of Europe and the USA (Liu et al. 2013). China exceeds the combined use of chemical fertilizers in USA and Northern Europe, and accounts for >30% of total world use (Zhang, W. Ma, L. et al. 2013; Zhang, F. et al. 2014). The FAO now estimates that up to 30% of agricultural land has been degraded, and water resources widely contaminated (FAO, 2013; Strokal et al. 2016). When characterising China's sociogenic climate change from agriculture, it is important to recognize the significance of rice as an emitter of two powerful greenhouse gases, methane and nitrous oxide now amplified by overfertilization. This is a linked production-consumption specificity, a policy of food security and self-sufficiency especially applied to rice as a major cultural component of national diet. The environmental impacts are multi-dimensional: acidification of the soil, eutrophication of surface water, and an augmented level of nitrous oxide emissions, now accounting for 10-15% of China's GHG footprint. The effect of subsidising use to 250 million smallholders, lacking the skills and technologies for a minimizing and efficient use of fertilizers, demonstrates the sociogenic distinctiveness of Chinese agriculture, combining landownership with food policy dimensions.

Before turning to the major shift in food policy that saw China joining the WTO in 2001, so decoupling food security from food self-sufficiency, China responded significantly to its domestic agri-ecological crisis, again with a societally distinctive set of policy measures (Mu, Z. et al., 2014; Liu et al., 2015). Policies have been developed targeting the three key dimensions of land, water and fertilizer use (Wang, J. et al. 2010). As we will see, in marked contrast to Brazil, legislation with respect to the Chinese finitudes of land are directed against the constant reduction of agricultural land, with a 'red line' against falling below 1.8 billion mu (Wang, J. 2012b; Li et al. 2013). So legislation is aimed at limiting the conversion of agricultural land into urban, infrastructural or industrial uses (Jiang et al. 2013). It also aims to conserve the quality of agricultural land against further degradation. The ecological crisis of China's water resources has in turn been addressed by three 'red lines', relating to competing water uses (agricultural, industrial and domestic), the efficiency of water use, and protection against pollution (Zuo et al. 2014). Given China's high level of reliance on energy-intensive abstraction of groundwater for agriculture, water efficiency also promises a potential reduction in energy demand as a measure of GHG mitigation (Wang, J. et al 2012a). Finally, from 2015 measures have been adopted with the ultimate objective of capping the total amount of fertilizer use, with zero increase from 2020, preceded by a limitation of 1% increase per annum from 2016 (Liu et al. 2015). This policy has been combined with widespread experimentation in agronomies to increase yield with reductions in emissions from nitrogen fertilizers. Some of these experiments have involved intensive support to Farmer Professional Cooperatives, raising levels of knowledge and use of new hybrids and rotational systems (Zhang, F. et al. 2013, 2014). A striking feature of these environmental regulations is their focus both on Chinese finitudes of land and water, and on the peculiarly Chinese sociogenic characteristics of pollution and GHG emissions from agriculture. However, experts interviewed all stressed the significant barriers to implementation of these policies, of which the fragmentation of farms and rural out-migration, and changing demographics of the left-behind rural populations were particularly daunting. Moreover, modernised and scaled-up intensive pig-rearing enterprises, relatively unregulated, were now adding a new source of pollution and GHG emissions (Xu et al. 2016; Strokal, et al. 2016).

Pigs form a useful bridging link to the other major shift in Chinese food and agriculture policy, raising quite different aspects to sociogenic climate change. From the late 1990s, it had become clear that China would no longer be capable of feeding itself, and that was in part because China engaged in a nutrition transition involving a much wider section of the population eating more meat (Gale et al. 2015). So food security no longer equated to food self-sufficiency. The political imperative expanded beyond that of meeting the "basic needs" food security (Huang and Rozelle, 2009; Garnett and Wilkes, 2014; Hansen and Gale, 2014). As with rice, China's consumption culture of eating pork is a critical dimension of its sociogenic climate change, although, as we shall see, consumer westernization has also driven a rapid growth in eating beef (Bai et al. 2010). Thus, from 1980 to 2015, per capita increase of annual pork consumption has grown from 12 kg to over 40 kg, poultry from less than one to over ten kilograms, and beef, from under one to five kilograms (Hansen and Gale, 2014). The GHG impact of eating pork is less than a tenth that of eating beef, and poultry even less (Gill et al. 2015). Different countries have different nutrition transitions, with consequently different planetary impacts. Above all, in China per capita consumption then has to be multiplied by 1.35 billion to appreciate the scale of the impact of its distinctive nutrition transition.

To meet the changing and rapidly expanding food demand, from joining the WTO in 2001, China has progressively widened the scope of its imported food. However, again key policy decisions shaped this transition, with imported whole soyabeans as the major source of animal feed for pork production, a strategically important national meat industry, and a target for rapid intensification and modernisation (Sharma, S. 2014; Brown-Lima et al. 2010). Already a major exporter of soya to Europe and elsewhere, within ten years China had doubled Brazil's exports, now accounting for over half of its trade (FAOSTAT, 2015). Critically, China's agri-industrial strategy was to process whole soyabeans for animal feed by its national industry, rather than importing soymeal, and then produce the overwhelming proportion of its pork domestically (Sharma, 2014; Schneider and Sharma, 2014; Schneider, 2011). The impact on Brazilian land-use and land-extensification, to be discussed below, has been significant, with 11 million hectares now dedicated to producing soya to feed China's pork production and consumption. Many now argue that Chinese demand has been a primary driver of increased deforestation and carbon emissions from agriculture in Brazil (Peine, 2013; Fearnside and Figueiredo, 2015; Nepstad, 2009).

The production-distribution-consumption configuration for beef has taken a quite different trajectory from pork. The increasing proportion of beef in overall meat consumption has been delivered to a significant extent by the expansion of multinational fast-food retailers, McDonalds, Burger King, and KFC (Expert interviews, May 2016; Ma et al. 2006). One expert recalled how she was always rewarded with a McDonald's beefburger when she achieved the highest marks in her class at school. Declining national herds from the 1990s, only partially compensated by increased yields from a low productivity base, has meant that, unlike pork, China has imported beef on an increasing scale. In terms of its size of herd, the domination of holdings of under five head, typical of fragmented land holdings, has been slow to change (Waldron et al. 2015). Major global Brazilian multinationals have stepped in to fill the demand gap, especially following the opening up of direct imports to the Chinese mainland, rather than indirect ones either through Hong Kong, or the major smuggling trade via Vietnam and Laos of 400,000 tonnes annually (Waldron et al. 2010). Since 2010, Brazilian imports have exploded (Figure 1, below). There has also been a marked shift from importing whole frozen carcasses for butchering and processing within China, to pre-prepared packaged cuts ready for retailing (Interviews with Brazilian MNCs, December 2015, June 2016). So, increasing beef consumption has led to minimally increased demand for land in China, with cattle reared on an increasing scale in Brazil and Australia, and increasing proportion of added value captured by both Brazilian meat exporters and MNC retailers operating in China.

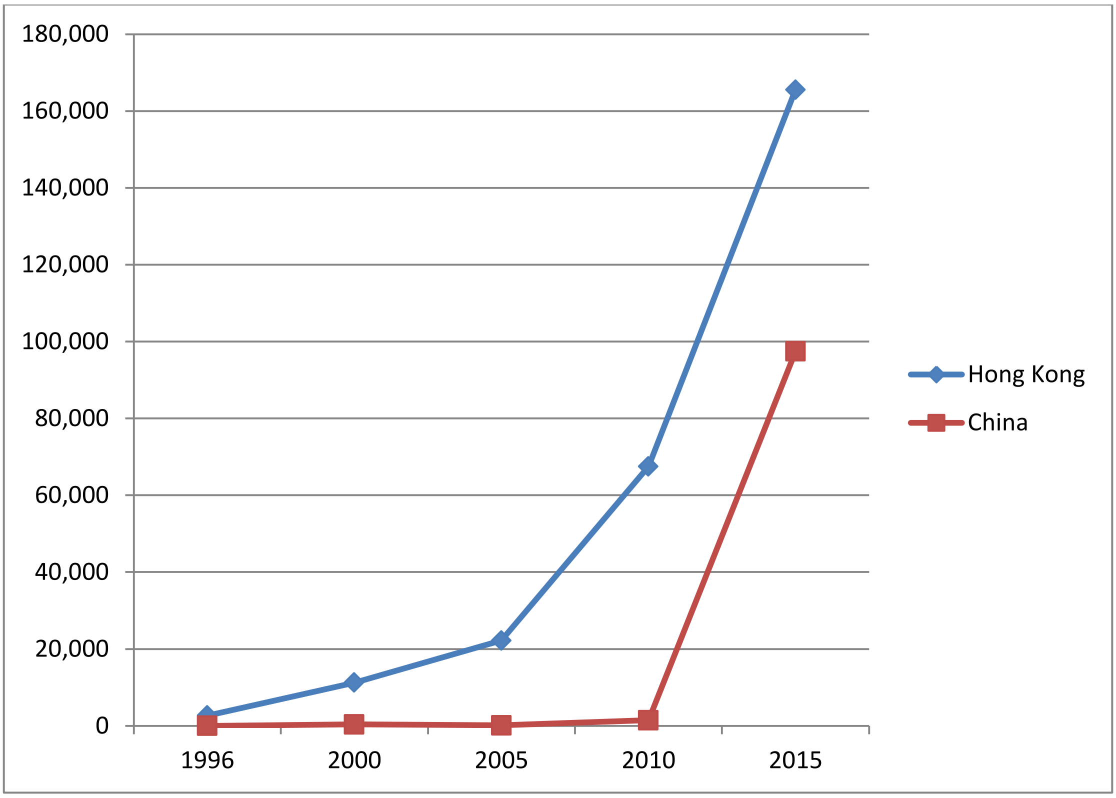

Figure 1. Brazilian beef exports to China in tonnes. *Source:* ABIEC, 2015.

Growing and changing food consumption in China, in particular its distinctive meat transition, clearly has major implications for GHG gas generation, alongside the ecological crisis of over-fertilization and intensification. It is important to signal, however, that the shift from the dominance of basic staples has not only been towards more meat, but also towards more fruit and vegetable varieties, the consumption of which has quadrupled from 100kg per capita in the mid-1980s to over 400kg in 2011, double that of European consumption (Gill et al. 2015). Moreover, China has recently issued guidelines to limit the growth of meat consumption, suggesting that the politics of consumption retains a strongly national character. Yet, overall the departure from food self-sufficiency, with only wheat and rice, no longer even maize, retaining the political objective of 95% domestic production, has been remarkable and rapid (Expert interviews, May 2016). However, as we have shown, China is distinctive in both production and consumption, and also distinctive in its trading patterns, characterised by a politically shaped and dominant bilateral relationship with Brazil. Its food sociogenic driver of climate change, is thus both within its own national territories and with its international trade relations. It does not do business anyhow, anywhere in a global market, but in a directed and channelled way, with a country which itself is distinctive in its export oriented agriculture, to which we now turn.

The Brazilian sociogenic trajectory

Although later to become strategically connected to China, the Brazilian sociogenic trajectory from land-use, land-use change and agricultural production of food could scarcely be in stronger contrast to China in terms of societal interactions with its environmental resources. As already noted, Brazil has many times more cultivated land and potentially cultivatable land, water and solar energy per capita than China. Much of the potentially cultivatable land – as a Brazilian ‘gift of nature’ – only became an effective agricultural resource as a consequence of high-tech agronomic and biotechnology innovation, driven by state-sponsored research, notably EMBRAPA, FAPESP, and CNPQ (Hopewell, 2016a; Harvey and McMeekin, 2005). Brazil could now be described as ‘the Middle East for food’, ranking first in the world as exporter of beef, poultry, coffee and orange juice; second for soya; third for corn; and fourth for pork (Hopewell, 2014; Wilkinson, 2009). Its carbon footprint signature corresponds to its geopolitical status: already by 2009, 65% of its GHG emissions derived from agriculture and deforestation, compared with China’s 15-20%, USA, Russia and Europe at 10% or less (UNDP, 2012). It is sociogenically in a league of its own for inducing climate change from agriculture.

In order to understand the dynamics of this distinctive sociogenesis, the same key dimensions will be considered as for China: scale of agricultural operations, linked to land use and land use change; state policy in relation to food production and trade; changing consumption patterns, domestically and internationally; and the emergent state and self-regulatory dynamics to mitigate climate change. It is important to stress that there is a Brazilian domestic dynamic, including its own meat consumption transition, which combines with distinctive Brazilian economic organisation of its export trade, whether for soya, or varieties of meat.

Initially, it is worth reflecting on the contrast between China and Brazil. While China was losing agricultural land to urbanisation and industry – one estimate was for 14.5 million hectares between 1979 and 2005 (Lichtenberg and Ding, 2010) – and then to pollution (see above), Brazil was expanding its agricultural land by 5 million hectares *every year* in the 1990s (Fearnside et al. 2013), through deforestation of the Legal Amazon. Since 2000, the rate of extensification (changing virgin into cultivated land) through deforestation has reduced remarkably, but to a level still amounting to some 800,000 hectares per year (Hecht, 2012). The two principal climate change sociogenic drivers related to land use in Brazil have been extensification and scale of production, of which the former has received overwhelming attention, particularly with respect to the Amazon biome (Hecht, 1993; Fearnside, 2001, 2005, 2008; Fearnside et al. 2013, 2015; Nepstad et al.2006).

The process and phases of extensification have been complex. But in very broad terms, from the 1970s to the mid-1990s extensification involved timber extraction followed by very low density pasturage of poor quality (one head of cattle per hectare).

This created a vast reservoir of what has now been deemed degraded pasture land (estimated between 50 and 100 million hectares). Since the welcome reduction in the rate of extensification (discussed below), two processes have followed, the expansion of soy production and intensification of cattle stocking, also releasing more land for alternative cultivation (soya, corn, sugarcane). Given the distinctively Brazilian focus on extensification, exploitation of the degraded pasture reservoir (indeed its restoration including reforestation), have been routinely portrayed as offering a sustainable way forward for growth in agricultural production (Macedo et al. 2012; Cardoso et al. 2016; Martha et al. 2012a; Pereira et al. 2012; Latawiec et al. 2014). Bold claims are made that with more efficient use of existing and historic pastureland, *all* demands on future agricultural production could be met until at least 2040 without further conversion of natural habitats (Strassburg et al, 2014). In this peculiarly Brazilian perspective, the sins of the past created the space for the virtues of the present. More sceptical voices point to a continuing pressure, especially from supplying soyabeans to China, for the further displacement of cattle ranching into the virgin Matto Grosso cerrado and Amazon biome by the expansion of soya cultivation into existing pastureland (Fearnside et al. 2013).

From the 1930s, if in very different ways in different periods, the state has played a key role in the process of extensification, by no means always directed at the expansion of agriculture or agricultural exports. Under the Generals (1964-1985), the creation of the reservoir of low-grade or degraded pasture from the 1970s was driven by a state objective of strategic territorial control during the Cold War to meet threats of peasant-led revolutions in Latin America (Oliveira, 2016). Thus, provisional landownership was given to clearing land in the Amazon and cerrado, on condition that minimal cultivation followed deforestation, a condition met by creating grassland and having one head of cattle per hectare. ‘Pasture was a state strategy not to produce protein but to occupy land.’ (Interview, JBS, Dec 2015). Apart from addressing issues of landlessness and rural displacement in the South and Centre South, a succession of policies across political regimes stimulated the conditions for the subsequent dramatic development of Brazilian agriculture for global markets in soya and beef. Vargas’ ‘March towards the West’ was followed by an alliance between Japan and Brazil for the expansion of soy production, now for the global market, in the cerrado, in particular in Matto Grosso (The Program for the Development of the Cerrados, 1975-1982). During this period, soy cultivation received heavy state subsidies. Up to 2001 and the entrance of China, exports of soymeal were predominantly for Europe, and soy oil to Asia. State-promoted soy-extensification was further supported by the policies of ‘Brazil in Action’ 1996-1999, and ‘Forward Brazil’, 2000-2003. As Fearnside has stressed, the state development of infrastructures of waterways, roads, rails and ports has throughout this long period created a ‘dragging effect’ pulling in cultivation through extensification (Fearnside, 2001). Finally, with the entrance of China into the WTO, state-to-state negotiations established favourable trading terms, including currency swaps for trading in soy to escape dollar hegemony (Oliveira, 2016; Hopwell, 2016b; Wilkinson and Wesz, 2013). These trade terms underpinned the massive expansion of land producing soybeans for the Chinese pork industry, so playing a key role in Brazil’s current GHG emissions from agriculture.

Aside from the physical infrastructures and export and trading state objectives, the Brazilian state has a long tradition of development of its agriculture knowledge infrastructures, placing it at the knowledge frontiers as much as, and oriented towards, its land frontiers. ESALQ, now a premier agricultural college and part of the University of Sao Paulo, was established in Piricicaba in the heart of one of the sugarcane growing areas, providing research and training from as early as 1901. In 1971, Embrapa, a public corporation funded by government established a decentralised network of research and technology centres, dedicated to developing different crops adapted to the frontier regions of extensification (Martha et al. 2012b; Correa and Schmidt, 2014). FAPESP, the state funded research organisation financed the development of genomics and biotechnology associated with Brazil’s primary crops, leading the world in the genomics of plant pathogens notably of Brazil’s global citrus industry (Harvey and McMeekin, 2005).

Although a very different political system from China, therefore, these different dimensions of state intervention underpinning the extensification process (state security, landownership, physical and knowledge infrastructures) combined to place Brazil in a position of the leading world food-producing power it has now become. Moreover, extensification, and a further shift to export orientation from the 1970s was accompanied by a major change in the scale of agricultural operations. This too reflected the distinctive model of Brazilian development combining state with domestic agri-capital and the multi-national commodity traders, the ABCD group. Industrialised, and high-tech agriculture, manifests the typical tripé (tripod) characteristics of other sectors of its economy (Evans, 1979). As a consequence, the Brazilian agricultural sector is strongly bifurcated between the large-scale export-oriented producers and the small and medium scale farms, more directed towards the domestic market. As we will see, this alliance between large domestic capital, multinationals and the state significantly shaped the subsequent environmental policies and regulation of land-use in Brazil.

In the most recent 2006 census of landholdings, the 1% of farms with holdings of over 1000 hectares occupy 45% of all cultivated area, while the 49.4% of farms with holdings of less than 10 hectares occupy a mere 2.2% of cultivated area. Farms of over 100 hectares, mostly those involved in export oriented supply chains, constituting 10% of all farms, occupy 80% of all Brazilian farmland (USDA, 2016). Although there is substantial variation in soy farm size, the process of expansion into degraded pasture for export-led soy production in the Centre West (Mato Grasso) involved the emergence of large, even mega-scale, farms (Macedo et al. 2012; Mier y Terán Giménez Cacho, 2016), such as the Roncador Group farm with 150,000 hectares, and the Amaggi Group Tanguro farm with 80,000 hectares. The scaling up of units of production, moreover, was closely associated with the formation of supply chains dominated by the ABCD group and indigenous Brazilian agri-capital (Jepson et al. 2010; Garrett et al. 2013). To appreciate the significance of these scales, these mega-farms are up to *450,000 times* larger than the average Chinese farm, and even the typical Brazilian small household farm is more than 100 times larger than its Chinese counterpart.

A parallel bifurcation has occurred with beef production, typified again at one end of the scale by Gruppo Roncador that added cattle to its soy production in an integrated agronomy, with a mega-herd of 50,000. By Brazilian standards, in the key beef producing area of Mato Grasso, the small scale cattle farms range from a few hundred head to 2,000, whereas in terms of quantity of animals and land, the dominant ranches raised herds of up to 15,000 (Cerri et al. 2016). Again, these herds are on a magnitude of scale greater than those to be found in China. However, the dynamics of scale are complex, and, as with China, politically and economically shaped. Thus, to prevent the earlier pattern of extensification at the fringes by small farmers being displaced by large ranchers, a policy of Settlement Projects has secured a substantial and continuing presence of smallholders (Pacheco and Poccard-Chapuis, 2012; Soler et al. 2014). However, these in turn are dominated by the beef processors, notably Marfrig and JBS, now also owner of Bertin, creating a pattern of small farmers providing large ranches with calves for fattening, which then go direct to processors via the pinch-point of their abattoirs. The insertion of smallholders into global and national-scale supply chains, under asymmetries of power in the market exchange, has been described as a new form of exploitation by transnational corporations (Pereira et al. 2016).

The processes of farming extensification, degraded pasturage, cattle intensification, and then expansion of both soy and cattle production have therefore led to a distinctive character of agriculturally driven sociogenic climate change in Brazil. Cattle intensification, releasing degraded pasture through 'land saving' has been widely heralded as mitigating climate change from extensification (Strassburg et al. 2014; Martha et al. 2012; Cohn et al. 2014; de Oliveira Silva et al. 2016). At the same time, however, the overall beef herd in Brazil has increased five times to its current level of over 200 million head from the early 1970s (Pereira et al.2012). JBS slaughters over 1000 head of capital per day, and Marfrig a similar number. Recent studies have demonstrated that GHG from cattle is consequently overwhelmingly (75%- 90%) from enteric fermentation and excreta producing respectively methane and nitrous oxide emissions (Cardoso et al. 2016; Cerri et al. 2016), rather than land clearing and deforestation. On the other hand, the soy production on previously degraded pasture, although nitrogen fixing and hence potentially beneficial at the point of Brazilian production, is dedicated to animal feed, whether in Europe or China, hence connected to a new configuration of meat production and meat consumption transitions with consequential climate change implications.

Although much attention has focused on export-driven agricultural growth, especially from China, as a primary source of deforestation and climate change

(Fearnside, 2013, 2015; Peine, 2013; Oliveira and Schneider, 2016), it is important to recognise Brazil's own domestic consumption dynamic, and, contrasting with China, its own self-sufficient meat transition. Although beef exports have risen dramatically by 672% from 1995-2013 from a very low base, domestic consumption has also grown by 41% over the same period, and still comprises 80% of total beef production (Figure 2). Where exports grew by 1.6 million tonnes per annum over this period, domestic consumption grew by 2.3 million tonnes per annum.

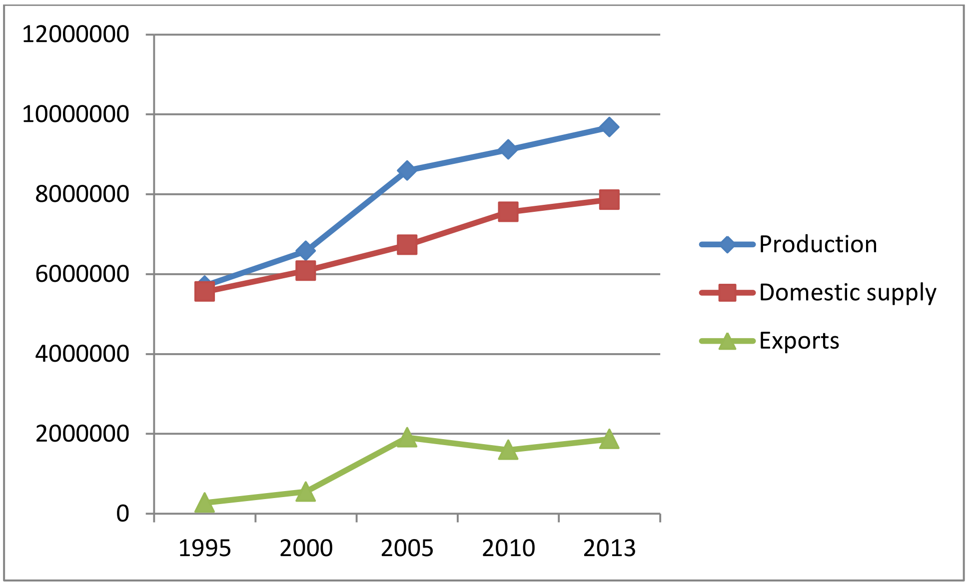

Figure 2. Brazil's Bovine meat production, domestic supply and exports (tonnes, per annum). Source: FAOSTAT, 2016)

From a sociogenic perspective, moreover, as discussed below, domestic supply is less tightly regulated than global export supply chains, and more likely to be responsible for the continuing levels of deforestation and low density pasturage. Again in contrast to China, Brazil's meat consumption culture is dominated by beef symbolised by the national institution of the *churrascaria* (meat barbecue) (Ribeiro and Corcao, 2013; Carvalho de Rezende et al. 2013). So, comparing meat transitions, Gill and colleagues have shown that per capita Brazilians eat double the amount of beef in 2011 that they did in 1961, at around 40kg per year by 2013 (ABIEC, 2016). Now also annually consuming a similar quantity of poultry per capita, their total per capita meat consumption exceeds European levels, and is on an upward curve in the direction of USA levels of meat consumption. By 2011, Brazilians were consuming 92.6 kg per capita, compared with Chinese consuming 52.4 kg per capita. Given the significance of beef consumption with its far greater GHG impact, they calculate that Brazilian per capita CO2 emissions from eating meat is almost ten times greater than China, although, of course, with a much smaller population of some 250 million (Gill et al. 2015).

If Brazilian food production and consumption is sociogenically distinctive for climate change, so too and relatedly are its mitigation policies, both in their focus and in their organisation. Whether for soy or for beef, the predominant almost exclusive focus has been on preventing deforestation and extensification particularly into the symbolic Amazon biome, and much less so into the Mato Grosso cerrado. As for politico-economic organisation, so too for climate change mitigation, the policies manifest distinctive blends of state and multi-national corporation combination in their organisation. The overarching state policy, originating in the 1960s as the Forest Code, has been strengthened successively, most critically with the establishment in 2012 of the Rural Environmental Registry (CAR), backed up by the Ministério Público Federal and a dedicated policing force, IBAMA. Cadastral registration of legally held land, and defined areas of reserved and indigenous land was enforced in particular by real time satellite monitoring of land-use change (INPE and PRODES). These Brazilian state instruments have been combined with post-Kyoto international instruments directed particularly at deforestation, the REDD+ and REDD++ carbon-offset trading policies

(Reducing Emissions from Deforestation and Forest Degradation) achieving some notable successes typified in Acre State in the Amazon biome (Hall, 2008; Alencar et al., 2012; Agrawal, et al. 2011; Nepstad et al. 2014). These policies and technologies of monitoring and regulating land use change in real time, using INPE (National Institute of Space Research) satellite tracking, are unique in the world, representing pioneering environmental supervision.

These state and international governmental measures have been significantly complemented and coordinated with a distinctively Brazilian combination of state and domestic and international multi-national corporations engaged in preventing the sourcing of food from the Amazon biome and from newly converted virgin land. Thus, for soya, the Roundtable for Responsible Soy was established (2006), followed by the more effective Soy Moratorium (2006). The latter, interestingly, was established in part as a consequence of an intervention by Greenpeace, indirectly through McDonalds in Europe, in turn exerting pressure on Cargill, so subsequently embracing major soy producers, traders and processors (Abiove, Amaggi, Aprosoya, Cargill and Unilever) (Interviews with all the above named, August, September, December 2015). The moratorium has recently been extended to 2020, and from an early stage had government involvement, in particular the CAR and INPE land-use change monitoring. Likewise for cattle, a combination of state and multinational corporations, this time exclusively Brazilian, established a similar sustainability roundtable, the Grupo de Trabalho da Pecuária Sustentável (2009) and developed the so-called G4 agreement (2009), initiated in Pará state, but then extended to the adjacent states. These state-self-regulatory combines for beef were also designed to prevent the sourcing of cattle from the Amazon biome and newly converted virgin land (Interviews with JBS and ABIPEC, December 2015, January 2016).

A key feature of this politico-economic organisation of climate change mitigation concerns enforcement and implementation, on the one hand, and land coverage on the other. Notably, the multinationals work with environmental NGOs (The Nature Conservancy, Greenpeace, WWF, Instituto Centro de Vida), certainly to enhance their sustainability branding for domestic and international markets, [2] as well as state enforcement of CAR. Cargill, JBS and Marfrig all use INPE satellite tracking and their own dedicated software (versions of DEGRAD, DETER and PRODES) to police their supply chains in real time. Across all the large scale soy and cattle producers, and their respective trade bodies, there is a widespread insistence that self-regulation on its own is insufficient without the complementary coordination with CAR and the enforcement agency of the Ministry for Federal Prosecution and IBAMA. Cargill refuses to use aggregated supply from upstream small producers in its supply chain that it cannot trace. Marfrig and JBS exclude any transgressors of CAR from their supply chains – JBS barred over 2000 ranches in 2015 (Gibbs et al. 2016). However, these big players engaged in these state-cum-self-regulatory combines only control 50-60% of the market, destined for export. Domestic supply falling outside either state or corporation capacity for real time monitoring and enforcement no doubt contributes to the continuing levels of deforestation.

> 'Even if you put JBS and Marfrig together in the Amazon region they only purchase 40% of the total cattle. So you have 60% of the market operating without rules.' (Interview, JBS, December 1, 2015).

[2] JBS announced that its pioneering Novo Campo project secured branding for sustainable hamburgers from Arcos Dourados, McDonald's brand operator in Latin America (August, 17th 2016).

Finally, a few demonstrator projects are oriented to sustainable intensification of agriculture, such as JBS's Novo Campo and the BRF-Sadia Lucas do Rio Verde farm reducing the carbon footprint of both beef and soy in an integrated agronomies. These promising ecological innovations are marginal to the main regulatory orientation towards limiting extensification, on the one hand, and are of limited countervailing influence on the overall growth in meat production and consumption, domestically and internationally, on the other.

To close this section, the distinctively Brazilian dynamics of sociogenesis of climate change *and its politics of climate change mitigation* could be encapsulated in one person: Blairo Maggi. He is the largest soy producer in the country and representative of Brazilian agri-capital; trades through multinational commodity companies (Cargill, etc.); and expanded soy cultivation into the cerrado, fuelling meat transitions across the world. He has held key political positions as Mato Grasso State Governor and Senator at the heart of the Brazilian state apparatus over a long period. And he is a principal player in the self-regulatory Soy Moratorium.

Contrasting sociogenic trajectories and the attraction of opposites

The concept of sociogenic climate change is a complex one, involving different dimensions of the interaction between political economies and their resource environments. In this paper, we have focused on food rather than energy or other economic activities, but the analytical framing is open to all areas of economic activity involving such interactions. The trajectories analysed above have highlighted some key dimensions especially but not exclusively relevant to agriculture and food production: political systems; economic configurations of markets, producers, processors and traders; land holding property rights and scales; and consumption patterns. In a Polanyian spirit, we also emphasise the distinctiveness of both movement and socio-political countermovement manifest in climate change mitigation policies evident in historical trajectories, as an integral part of understanding sociogenic climate change dynamics. The contrasting trajectories across these dimensions are portrayed in Table 1 below.

One key conclusion from this analysis is that different trajectories of interaction between socio-politico-economic systems and their resource environments generate different GHG footprints. This is at the core of the concept of sociogenesis. Each of the dimensions of this interaction (political systems, landholding, agronomies, consumption etc.) are important in their own right. But only in combination, at the societal level, do they together, and over historical transformations, generate their distinctive dynamics of climate change. How and which greenhouse gases are emitted relate to the organisation of land holdings, and consequently to agronomies at different scales. Rice or wheat production in China, even with small-holdings, can be regionally monocropping, but with totally different agronomies from the large-scale monocropping of soya or beef in Brazil. Politics runs throughout, across all dimensions. And all are conditioned by the naturally given resource environments. Analysed holistically in a Polanyian manner, moreover, the contrasting movements of unsustainable economic growth in Brazil and China have been modified to some extent by nationally distinctive counter-movements of environmental regulation. Sociogenic analysis embraces both movement and countermovement. Finally, in both cases it remains a wide open question whether their respective policy responses – including

	China	Brazil
Resource environment	Relative agricultural land scarcity, reducing through urbanisation and industrial development. Uneven water distribution, with areas of high aridity.	Relative land abundance and unconverted forest and savannah. Relative abundance of water, but under threat from climate change.
Political economic system	Central command economy with market socialist reforms from late 1980s.	Military dictatorship, development state, and 'tripod' political economy of state, large domestic and international corporations
Land ownership and scale	Highly fragmented minuscule household farms from 1989, with increasing fluidity in land leasing, underpinned by continued state land ownership.	Bifurcated landownership between small/medium household farms with mega-farms dominating landownership.
Food security and self-sufficiency	Policy of food self-sufficiency until joining WTO in 2001. Key grain crops (rice, wheat) self-sufficient. Increasing imports especially of soya, corn and meat.	Food self-sufficient and secure, although high levels of inequality.
Agricultural productive systems	Intensive agriculture with high chemical inputs, and low mechanisation. Stalled infrastructure development. Small scale production.	Expansion through extensification, followed by exploitation of degraded pasturelands. High-tech mechanised industrial agriculture on large scale farms.
Domestic and international market orientation	Domestic for food, globalised for manufacturing, IT, clothing, etc.	Strong export orientation. Dominant global food exporter for meat, soy, orange, coffee….
Consumption and meat transitions	Increasing consumption of meat from a low average level, dominated by pork, but beef emerging.	Meat eating culture, especially beef, on an upward per capita curve already above average European levels.
Greenhouse gas footprint signatures	Nitrous oxide from overfertilisation, methane from rice, pig slurry.	CO2 from land use change and deforestation. Methane from cattle enteric fermentation.
Climate change mitigation	Central command "Red Lines" on agricultural land reduction, chemical fertiliser use, water pollution and use. Directives to curb meat consumption.	State regulation on land-use change and deforestation, combined with state-corporate self-regulation restricting further land exensification especially in Amazon biome.

Table 1. Trajectories of sociogenic climate change: China and Brazil

their COP21 Paris commitments – adequately recognise the scale of the challenge of growing and changing food demand, and the consequent pressures on land use and land use change.

In addressing the sociogenic character of climate change and the distinctiveness of national trajectories, it might be argued that the significance of globalisation – whether of economic activity or of the planetary aggregation of greenhouse gases – is being underplayed. The Brazil-China linkage has been highlighted for a purpose because on the one hand China's food policy and needs may indeed create a demand for imported soya, and, on the other hand, Brazil was already in a path-dependent trajectory of exporting soya to Europe before its rapid growth of exports to China. Brazilian export trade of food is certainly international, but it is not uniformly global. Indeed, whether for beef, poultry, soyabeans and soyameal, its trade patterns contrast strongly both with Argentina and other Latin American countries, but also with the USA (Koopman and Laney, 2012). The specificity of Brazilian and Chinese trajectories, it can be argued, also generates the specific and distinctive trade connections between them. Opposites attract.

Whether for domestic or international markets, the theoretical perspective developed here advocates a configurational approach as its unit of analysis, integrating production, distribution, exchange and consumption, for soya or beef, domestically or internationally. Interestingly, the emergent configurational connections between Brazil and China differ as between beef and soy (See Diagram 1 below). They differ as a consequence directly of Chinese policy, environmental resources, and capacities, and of the role of Brazilian and multinational agents. Thus, China only imports soybeans from Brazil, processes them, and grows and up-scales its own pork industry. In contrast, Brazilian beef multinational combine the roles of processor and trader, including provision of packaged and processed products ready for the supermarket shelf in China. The economic organisation of the trade connections for soy and beef, which also has its GHG generation consequences as to where and how GHG is generated, thus exemplifies the need for a sociogenically refined rather than amorphously 'global' anthropogenic approach.

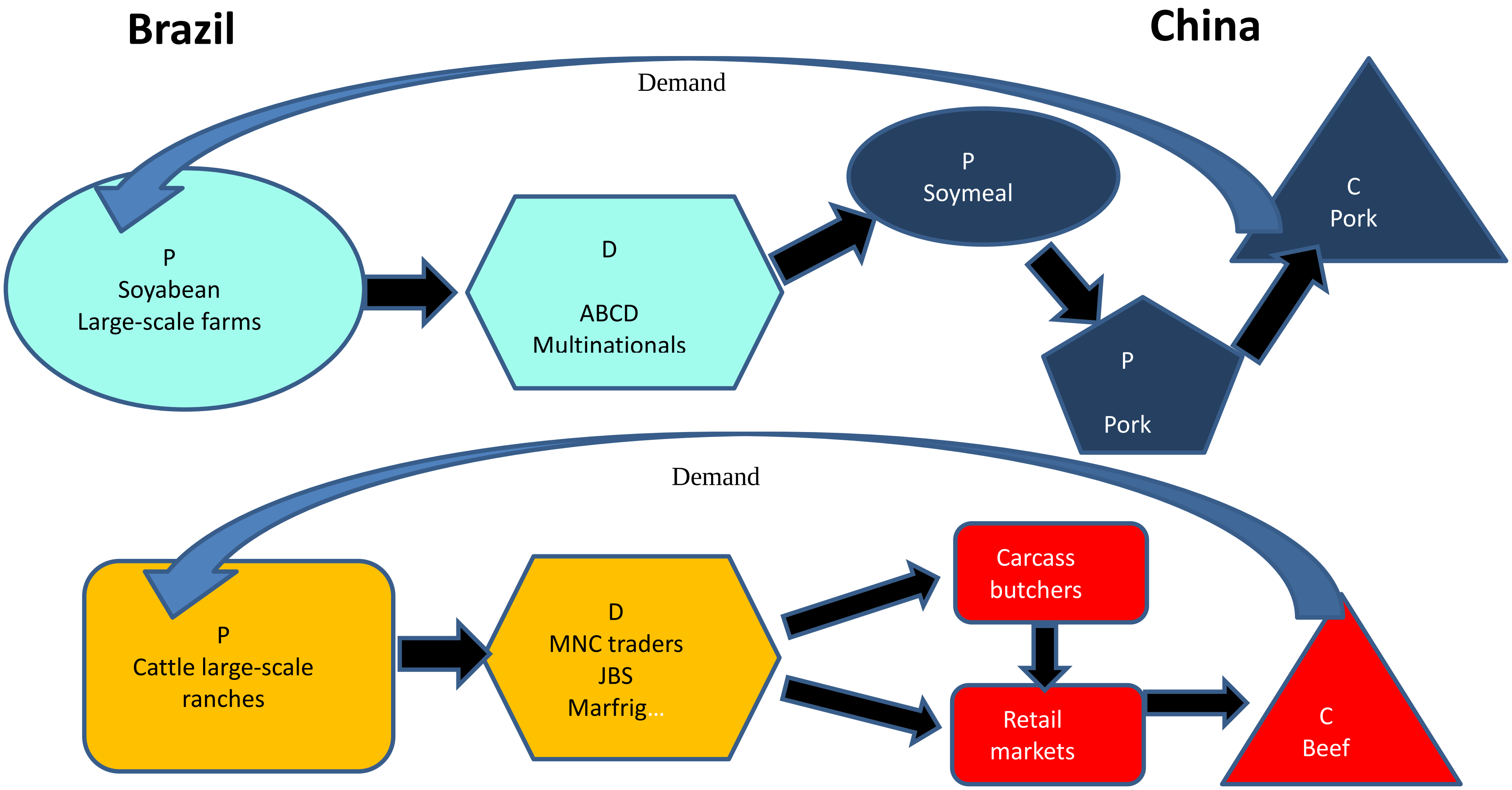

Diagram 1. Opposites Attract: The Production (P)-Distribution (D)-Exchange-Consumption (C) configurations for beef and soya

Conclusion: units of analysis and policy implications

A key feature of the COP21 Paris Agreement (2016) was the Nationally Determined Contribution to ensuring that the world control their emissions in order to prevent global warming by more than 2 degrees. Thus, the negotiating framework recognised the continuing significance of states in their capacity to control emissions on their national territory. Conversely, were a major state to renege on its commitments to use this capacity, there would be severe consequences for the world in the absence of other means of enforcement. Indeed, the significance of a nation state policy perspective is borne out by the above analysis of China's Red Lines and Brazil's Forest Code and moratoria.

However, the sociogenic perspective on climate change highlights two important, and often connected, deficits in this perspective: a one-sidedly productivist account of emissions and emitters (leaving out consumption and demand); and the failure to address sustainability regulation of international trade (Norse et al. 2014). Ironically, the sustainability self-regulation discussed above for McDonald's "sustainable hamburgers" and the McDonald-Cargill-Soy Moratorium initiative, for all its many limitations, partially addresses this double deficit. Multinational global traders respond to markets, NGOs, and environmental movements in consumer countries when they seek sustainability branding of their products. In many interviews, across a range of such companies, it was stressed that they could not sell half a chicken without sustainability credentials in one market and the other half with sustainability credentials in another market, as it were. Unlike the chicken (soy, beef, or whatever), sustainability credentials and reputation are seen as indivisible, at least to many large-scale, multi-country, producers and traders.

This paper takes configurations of production, distribution, exchange and consumption, at whatever scale, local, national or international, as its unit of analysis. It does so, arguing that the dynamics driving climate change are best understood in configurational terms. In so doing, a false antithesis between producers or producer countries and consumer or consumer countries is avoided. So it matters that China is consuming more and more meat; and it matters how and where, by what agronomies, animal feed and meat is produced in Brazil. They are sociogenically significant, separately *and* together. Policies need to be focused on the dynamics of configurational change, whether these are entirely within national boundaries, or whether they involve the specific connections of international trade. Climate change mitigation policies need to be adapted to configurations and configurational transformations. They entail a sustainability politics of consumption as much as of production and trade. In taking this approach, bilateral trade agreements related to the dynamics connecting producer with consumer countries, such as those between China and Brazil, can focus on what needs to be done on both sides of the connection. Given the scale and rapidity of changing food demand and agricultural production and their significance for climate change, radical new policy approaches adapted to their sociogenic specificities are ever more urgent.

References

ABIEC (Associação Brasiliera dos Indústrias Exportadores de Carne). 2015. Annual Statistical Report. www.abiec.com.br

Agrawal, A., Nepstad, D. and Chhatre, A., 2011. Reducing emissions from deforestation and forest degradation. *Annual Review of Environment and Resources*, *36*, pp.373-396.

Alencar, A., D. Nepstad, E. Mendoza, B. Soares-Filho, P. Moutinho, M.C.C. Stabile, D.McGrath, S. Mazer, C. Pereira, A. Azevedo, C. Stickler, S. Souza, I. Castro, O. Stella.2012. *Acre State's Progress Towards Jurisdictional REDD+*. Instituto de Pesquisa Ambiental da Amazônia, Brasília, DF, 53p.

Bai, J., Wahl, T.I., Lohmar, B.T. and Huang, J., 2010. Food away from home in Beijing: Effects of wealth, time and "free" meals. *China Economic Review*, 21(3), 432-441.

Brown-Lima, C., Cooney, M. and Cleary, D., 2010. *An overview of the Brazil-China soybean trade and its strategic implications for conservation.* The Nature Conservancy, Brazil.

Cardoso, A.S., Berndt, A., Leytem, A., Alves, B.J., de Carvalho, I.D.N., de Barros Soares, L.H., Urquiaga, S. and Boddey, R.M., 2016. Impact of the intensification of beef production in Brazil on greenhouse gas emissions and land use. *Agricultural Systems*, *143*, pp.86-96.

Carvalho de Rezende, D. and Alberto Rodrigues Silva, M., 2013. Eating-out and experiential consumption: a typology of experience providers. *British Food Journal*, *116*(1), pp.91-103.

Castree, N. 2015. 'Changing the Anthropo(s)cene Geographers, global environmental change and the politics of knowledge.' *Dialogues in Human Geography*, 5(3), 301-316.

Cerri, C.C., Moreira, C.S., Alves, P.A., Raucci, G.S., de Almeida Castigioni, B., Mello, F.F., Cerri, D.G.P. and Cerri, C.E.P., 2016. Assessing the carbon footprint of beef cattle in Brazil: a case study with 22 farms in the State of Mato Grosso. *Journal of Cleaner Production*, *112*, pp.2593-2600.

Cohn, A.S., Mosnier, A., Havlík, P., Valin, H., Herrero, M., Schmid, E., O'Hare, M. and Obersteiner, M., 2014. Cattle ranching intensification in Brazil can reduce global greenhouse gas emissions by sparing land from deforestation. *Proceedings of the National Academy of Sciences*, *111*(20), pp.7236-7241.

Correa, P. and Schmidt, C., 2014. Public Research Organizations and Agricultural Development in Brazil: How Did Embrapa Get It Right?. *World Bank-Economic Premise*, *145*, pp.1-10.

Crutzen, P.J. and Stoermer, E.F., 2000. The Anthropocene IGBP Newsletter, 41. *Royal Swedish Acdemy of Sciences, Stockholm, Sweden*.

de Oliveira Silva, R., Barioni, L.G., Hall, J.A.J., Matsuura, M.F., Albertini, T.Z., Fernandes, F.A. and Moran, D., 2016. Increasing beef production could lower greenhouse gas emissions in Brazil if decoupled from deforestation. *Nature Climate Change*, 6, 493-98.

Evans, P. 1979 *Dependent Development: the alliance of multinational, national and local capital in Brazil*. Princeton: Princeton University Press.

FAO. 2013. *Guidelines to Control Water Pollution from Agriculture in China.* Rome.

Fearnside, P.M., 2001. Soybean cultivation as a threat to the environment in Brazil. *Environmental Conservation*, *28*(01), pp.23-38

Fearnside, P.M., 2005. Deforestation in Brazilian Amazonia: history, rates, and consequences. *Conservation biology*, *19*(3), pp.680-688.

Fearnside, P.M., 2008. The roles and movements of actors in the deforestation of Brazilian Amazonia. *Ecology and society*, *13*(1), p.23.
Fearnside, P.M., Figueiredo, A.M. and Bonjour, S.C., 2013. Amazonian forest loss and the long reach of China's influence. *Environment, development and sustainability*, *15*(2), pp.325-338.
Fearnside, P.M. and Figueiredo, A.M., 2015. 'China's Influence on Deforestation in Brazilian Amazonia: A Growing Force in the State of Mato Grosso.' *BU Global Economic Governance Initiative Discussion Papers*, *3*
Gale, H.F., Hansen, J. and Jewison, M., 2015. China's growing demand for agricultural imports. *USDA-ERS Economic Information Bulletin*, (136).
Garrett, R.D., Lambin, E.F. and Naylor, R.L., 2013. Land institutions and supply chain configurations as determinants of soybean planted area and yields in Brazil. *Land Use Policy*, *31*, pp.385-396.
Garnett, T. and Wilkes, A., 2014. *Appetite for Change. Social, Economic and Environmental Transformations in China's Food System*. Food Climate Research Network. www.fcrn.org.uk
Gibbs, H.K., Munger, J., L'Roe, J., Barreto, P., Pereira, R., Christie, M., Amaral, T. and Walker, N.F., 2016. Did Ranchers and Slaughterhouses Respond to Zero-Deforestation Agreements in the Brazilian Amazon?. *Conservation Letters*, *9*(1), pp.32-42.
Gill, M., Feliciano, D., Macdiarmid, J. and Smith, P., 2015. 'The environmental impact of nutrition transition in three case study countries.' *Food Security*, *7*(3), 493-504.
Guo, H., Jolly, R.W. and Zhu, J., 2007. Contract farming in China: perspectives of farm households and agribusiness firms. *Comparative Economic Studies*, *49*(2), 285-312.
Hall, A.L. 2008. 'Better RED than dead: paying the people for environmental services in Amazonia', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363, 1925-32.
Hansen, J. and Gale, F., 2014. China in the next decade: rising meat demand and growing imports of feed. *Amber Waves*. http://www.ers.usda.gov/amber-waves/2014-april/china-in-the-next-decade-rising-meat-demand-and-growing-imports-of-feed.aspx#.V71ukaLKZc4
Harvey, M., 2014. The Food-Energy-Climate Change Trilemma: Toward a Socio-Economic Analysis. *Theory, Culture & Society*, p.0263276414537317.
Harvey, M. and Pilgrim, S., 2011. The new competition for land: food, energy, and climate change. *Food Policy*, *36*, pp.S40-S51.
Harvey, M. and McMeekin, A. 2005. 'Brazilian genomics and bioinformatics: instituting new innovation pathways in a global context.' *Economy and Society*, 34:4, 634-658.
Hecht, S.B., 1993. The logic of livestock and deforestation in Amazonia. *Bioscience*, *43*(10), pp.687-695.
Hecht, S.B., 2012. From eco-catastrophe to zero deforestation? Interdisciplinarities, politics, environmentalisms and reduced clearing in Amazonia. *Environmental conservation*, *39*(01), pp.4-19.
Hopewell, K., 2014. The transformation of state-business relations in an emerging economy: The case of Brazilian agribusiness. *Critical perspectives on international business*, *10*(4), pp.291-309.
Hopewell, K., 2016. The accidental agro-power: constructing comparative advantage in Brazil. *New Political Economy*, pp.1-19.

Hopewell, K., 2016. *Breaking the WTO: How Emerging Powers Disrupted the Neoliberal Project*. Stanford University Press.

Huang, J. and Rozelle, S., 2009. *Agricultural development and nutrition: the policies behind China's success*. World Food Programme.

Huang, P.C., Yuan, G. and Peng, Y., 2012. Capitalization without proletarianization in China’s agricultural development. *Modern China*, p.0097700411435620.

Jepson, W., Brannstrom, C. and Filippi, A., 2010. Access regimes and regional land change in the Brazilian Cerrado, 1972–2002. *Annals of the Association of American Geographers*, *100*(1), pp.87-111.

Jiang, L., Deng, X. and Seto, K.C., 2013. The impact of urban expansion on agricultural land use intensity in China. *Land Use Policy*, *35*, pp.33-39.

Kerkvliet, B.J.T. and Selden, M., 1998. ‘Agrarian transformations in China and Vietnam.’ *The China Journal*, (40), pp.37-58.

Koopman, R.B. and Laney, K., 2012. Brazil: Competitive Factors in Brazil affecting US and Brazilian Agricultural Sales in selected third country markets. *US International Trade Commission. Publication*, *4310*.

Latawiec, A.E., Strassburg, B.B.N., Valentim, J.F., Ramos, F. and Alves-Pinto, H.N., 2014. Intensification of cattle ranching production systems: socioeconomic and environmental synergies and risks in Brazil. *animal*, *8*(08), pp.1255-1263.

Li, G., Zhao, Y. and Cui, S., 2013. ‘Effects of urbanization on arable land requirements in China, based on food consumption patterns.’ *Food security*, *5*(3), pp.439-449.

Lichtenberg, E. and Ding, C., 2008. Assessing farmland protection policy in China. *Land Use Policy*, *25*(1), pp.59-68.

Liu, X., Vitousek, P., Chang, Y., Zhang, W., Matson, P. and Zhang, F., 2015. ‘Evidence for a Historic Change Occurring in China.’ *Environmental science & technology*, *50*(2), pp.505-506.

Liu, X., Zhang, Y., Han, W., Tang, A., Shen, J., Cui, Z., Vitousek, P., Erisman, J.W., Goulding, K., Christie, P. and Fangmeier, A., 2013. ‘Enhanced nitrogen deposition over China.’ *Nature*, *494* (7438), pp.459-462.

Lu, Y., Jenkins, A., Ferrier, R.C., Bailey, M., Gordon, I.J., Song, S., Huang, J., Jia, S., Zhang, F., Liu, X. and Feng, Z., 2015. ‘Addressing China’s grand challenge of achieving food security while ensuring environmental sustainability.’ *Science advances*, *1*(1), p.e1400039.

Ma, H., Huang, J., Fuller, F. and Rozelle, S., 2006. ‘Getting rich and eating out: consumption of food away from home in urban China.’ *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *54*(1), 101-119.

Macedo, M.N., DeFries, R.S., Morton, D.C., Stickler, C.M., Galford, G.L. and Shimabukuro, Y.E., 2012. ‘Decoupling of deforestation and soy production in the southern Amazon during the late 2000s.’ *Proceedings of the National Academy of Sciences*, *109*(4), pp.1341-1346.

Martha, G.B., Alves, E. and Contini, E., 2012a. Land-saving approaches and beef production growth in Brazil. *Agricultural Systems*, *110*, pp.173-177.

Martha, G.B., Contini, E. and Alves, E., 2012b. ‘Embrapa: its origins and changes. In Beir, W. *The regional impact of national policies: the case of Brazil*,. Edward Elgar. Cheltenham. 204-26.

McAlpine, C.A., Etter, A., Fearnside, P.M., Seabrook, L. and Laurance, W.F., 2009. ‘Increasing world consumption of beef as a driver of regional and global change: A call for policy action based on evidence from Queensland (Australia), Colombia and Brazil.’ *Global Environmental Change*, *19*(1), pp.21-33.

Mier y Terán Giménez Cacho, M., 2016. 'Soybean agri-food systems dynamics and the diversity of farming styles on the agricultural frontier in Mato Grosso, Brazil.' *The Journal of Peasant Studies*, *43*(2), pp.419-441.

Moore, J.W., 2010. The End of the Road? Agricultural Revolutions in the Capitalist World-Ecology, 1450–2010. *Journal of Agrarian Change*, *10*(3), pp.389-413.

Moore, J. W. 2015. 'Anthropocene or Capitalocene? On the origins of our crisis.' *Capitalism in the Web of Life: Ecology and the Accumulation of Capital*. Verso Books. London

Mu, Z., Bu, S. and Xue, B., 2014. Environmental legislation in China: Achievements, challenges and trends. *Sustainability*, *6*(12), pp.8967-8979.

Mu, R. and Giles, J., 2014. 'Village political economy, land tenure insecurity, and the rural to urban migration decision: evidence from China.' *World Bank Policy Research Working Paper*, (7080).

Naess, P. and Price, L. 2016. *Crisis System: A critical realist and environmental critique of economics and the economy*. Routledge. London.

Nepstad, D.C., Stickler, C.M. and Almeida, O.T., 2006. 'Globalization of the Amazon soy and beef industries: opportunities for conservation.' *Conservation Biology*, *20*(6), 1595-1603.

Nepstad, D., McGrath, D., Stickler, C., Alencar, A., Azevedo, A., Swette, B., Bezerra, T., DiGiano, M., Shimada, J., da Motta, R.S. and Armijo, E., 2014. Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains. *Science*, *344*(6188), pp.1118-1123.

Norse, D., Lu, Y. and Huang, J., 2014. 'China's food security: Is it a national, regional or global issue?'. In Brown, K. Ed. *China and the EU in Context* Palgrave Macmillan UK. 251-302

Norse, D. and Ju, X., 2015. 'Environmental costs of China's food security.' *Agriculture, Ecosystems & Environment*, *209*, pp.5-14.

Oliveira, G.D.L., 2016. The geopolitics of Brazilian soybeans. *The Journal of Peasant Studies*, *43*(2), pp.348-372.

Oliveira, G.D.L. and Schneider, M., 2016. The politics of flexing soybeans: China, Brazil and global agroindustrial restructuring. *The Journal of Peasant Studies*, *43*(1), pp.167-194.

Pacheco, P. and Poccard-Chapuis, R., 2012. The complex evolution of cattle ranching development amid market integration and policy shifts in the Brazilian Amazon. *Annals of the Association of American Geographers*, *102*(6), pp.1366-1390.

Patel, R., 2013. The long green revolution. *The Journal of Peasant Studies*, *40*(1), pp.1-63.

Peine, E.K., 2013. 'Trading on pork and beans: agribusiness and the construction of the brazil-china-soy-pork commodity complex.' In James, H.S. Ed. *The ethics and economics of agrifood competition* (pp. 193-210). Springer Netherlands.

Pereira, P.A.A., Martha, G.B., Santana, C.A. and Alves, E., 2012. The development of Brazilian agriculture: future technological challenges and opportunities. *Agriculture & Food Security*, *1*(1), p.1.

Pereira, R., Simmons, C.S. and Walker, R., 2016. Smallholders, agrarian reform, and globalization in the Brazilian Amazon: Cattle versus the environment. *Land*, *5*(3), p.24.

Ribeiro, C.D.S.G. and Corcao, M., 2013. The consumption of meat in Brazil: between socio-cultural and nutritional values/O consumo de carne no Brasil: entre valores socioculturais e nutricionais. *Demetra: Food, Nutrition & Health*, *8*(3), pp.425-452.

Ribot, J., 2014. Cause and response: vulnerability and climate in the Anthropocene. *Journal of Peasant Studies*, *41*(5), pp.667-705.
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J. and Nykvist, B., 2009. 'A safe operating space for humanity.' *Nature*, *461*(7263), pp.472-475.
Ruddiman, W. F., Ellis, E. C., Kaplan, J. O., & Fuller, D. Q. 2015. 'Defining the epoch we live in.' *Science*, *348*(6230), 38-39.
Schneider, M., 2011. *Feeding China's pigs: implications for the environment, China's smallholder farmers and food security*. Institute for Agriculture and Trade Policy. .http://www. iatp. org/documents/china
Schneider, M., 2016. 'Dragon Head Enterprises and the State of Agribusiness in China.' *Journal of Agrarian Change*.
Schneider, M. and Sharma, S., 2014. *China's pork miracle? Agribusiness and development in China's pork industry.* Institute for Agriculture and Trade Policy. http://www. iatp. org/documents/china
Sharma, S., 2014. *The Need for Feed*. Institute for Agriculture and Trade Policy. www.iatp.org.
Soler, L.S., Verburg, P.H. and Alves, D.S., 2014. Evolution of land use in the Brazilian Amazon: From frontier expansion to market chain dynamics. *Land*, *3*(3), pp.981-1014.
Steffen, W., Grinevald, J., Crutzen, P. and McNeill, J., 2011. 'The Anthropocene: conceptual and historical perspectives.' *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, *369*(1938), pp.842-867.
Strassburg, B.B., Latawiec, A.E., Barioni, L.G., Nobre, C.A., da Silva, V.P., Valentim, J.F., Vianna, M. and Assad, E.D., 2014. 'When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil.' *Global Environmental Change*, *28*, pp.84-97.
Strokal, M., Ma, L., Bai, Z., Luan, S., Kroeze, C., Oenema, O., Velthof, G. and Zhang, F., 2016. Alarming nutrient pollution of Chinese rivers as a result of agricultural transitions. *Environmental Research Letters*, *11*(2), p.024014.
Tian, H., Lu, C., Ciais, P., Michalak, A.M., Canadell, J.G., Saikawa, E., Huntzinger, D.N., Gurney, K.R., Sitch, S., Zhang, B. and Yang, J., 2016. 'The terrestrial biosphere as a net source of greenhouse gases to the atmosphere.' *Nature*, *531*(7593), pp.225-228
UNDP 2012. The Emissions Gap Report. A UNEP Synthesis Report. URL: http://www.unep.org/pdf/2012gapreport.pdf
USDA, 2016. Economic Research Service. http://www.ers.usda.gov/topics/international-markets-trade/countries-regions/brazil/basic-information/ Downloaded 08.11.2016.
van der Ploeg, J.D. and Ye, J. eds., 2016. *China's Peasant Agriculture and Rural Society: Changing Paradigms of Farming*. Routledge. London.
Waldron, S., Jimin, W., Huijie, Z., Xiaoxia, D. and Mingli, W., (2015) *The Chinese beef cattle industry*. https://www.uq.edu.au/agriculture/docs/CAEG/China.pdf
Waldron, S., Brown, C. and Longworth, J., 2010. 'A critique of high-value supply chains as a means of modernising agriculture in China: The case of the beef industry.' *Food Policy*, *35*(5), 479-487.
Wang, J., Huang, J. and Rozelle, S., 2010. 'Climate change and China's agricultural sector: an overview of impacts, adaptation and mitigation.' ICTDS *Issue Brief No, 5*.

Wang, J., Rothausen, S.G.A., Conway, D., Zhang, L., Xiong, W., Holman, I.P. and Li, Y., 2012a. ‘China’s water–energy nexus: greenhouse-gas emissions from groundwater use for agriculture.’ *Environmental Research Letters*, *7*(1), p.014035.

Wang, J., Chen, Y., Shao, X., Zhang, Y. and Cao, Y., 2012b. ‘Land-use changes and policy dimension driving forces in China: Present, trend and future.’ *Land Use Policy*, *29*(4), pp.737-749.

Wilkinson, J. 2009. ‘The globalization of agribusiness and developing world food systems.’ *Monthly Review*, *61*(4), 38.

Wilkinson, J. and Wesz Junior, V.J., 2013. Underlying issues in the emergence of China and Brazil as major global players in the new South–South trade and investment axis. *International Journal of Technology Management & Sustainable Development*, *12*(3), pp.245-260.

World Bank. 2014a. *World Development Indicators*. http://wdi.worldbank.org

World Bank. 2014b *Changing food consumption patterns in China: implications for domestic supply and international trade*. China Economic Update 2014. www.worldbank.org/china

Xu, W., Zheng, K., Meng, L., Liu, X., Hartung, E., Roelcke, M. and Zhang, F., 2016. Concentrations and Emissions of Particulate Matter from Intensive Pig Production at a Large Farm in North China. *Aerosol and Air Quality Research*, *16*(1), pp.79-90.

Ye, J. 2015. ‘Land transfer and the pursuit of agricultural modernization in China.’ *Journal of Agrarian Change*, *15*(3), 314-337.

Ye, J., Wang, C., Wu, H., He, C. and Liu, J., 2013. Internal migration and left-behind populations in China. *Journal of Peasant Studies*, *40*(6), pp.1119-1146.

Zhang, F., Zhenling, C.U.I. and Zhang, W., 2014. Managing nutrient for both food security and environmental sustainability in China: an experiment for the world. *Frontiers of Agricultural Science and Engineering*, *1*(1), pp.53-61.

Zhang, F., Chen, X. and Vitousek, P., 2013. Chinese agriculture: An experiment for the world. *Nature*, *497*(7447), pp.33-35

Zhang, Q.F. and Donaldson, J.A., 2008. The rise of agrarian capitalism with Chinese characteristics: Agricultural modernization, agribusiness and collective land rights. *The China Journal*, (60), pp.25-47.

Zhang, W.F., Dou, Z.X., He, P., Ju, X.T., Powlson, D., Chadwick, D., Norse, D., Lu, Y.L., Zhang, Y., Wu, L. and Chen, X.P., 2013. New technologies reduce greenhouse gas emissions from nitrogenous fertilizer in China. *Proceedings of the National Academy of Sciences*, *110*(21), pp.8375-8380.

Zhang, X., Yin, S., Li, Y., Zhuang, H., Li, C. and Liu, C., 2014. ‘Comparison of greenhouse gas emissions from rice paddy fields under different nitrogen fertilization loads in Chongming Island, Eastern China.’ *Science of the Total Environment*, *472*, pp.381-388.

Zuo, Q., Jin, R., Ma, J. and Cui, G., 2014. ‘China pursues a strict water resources management system.’ *Environmental Earth Sciences*, *72*(6), pp.2219-2222.

Note: The concept of economy as instituted in space and time, scaling and multi-level, underpins the concept of sociogenesis as the interaction between instituted socio-economies and natural resource environments. To develop this further, as in abstract for IST.