Chapter 7:
International dimensions

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Implications of the vote to leave the European Union

This chapter was written before the results of the EU Referendum were known. Leaving the European Union is unlikely to change the overall scale of current and future risks from climate change, but in some areas it may affect policies and programmes important to address climate-related vulnerabilities.

If such policies and programmes are changed, it will be necessary for new UK measures to achieve the same or improved outcomes to avoid an increase in risk. The Adaptation Sub-Committee will consider the impact of the EU Referendum and the Government's response in its next statutory progress report on the UK National Adaptation Programme, to be published in June 2017.

Contents

Key messages

The three key dimensions of international risks and opportunities discussed in this chapter are (1) the global food system, (2) migration and displacement, and (3) geopolitical issues.

The causes and consequences of these risks and opportunities are inter-related. Managing the risks depends on co-ordination of information and knowledge across government departments, as well as international co-operation and multi-lateral processes. European-level institutions and interventions are also critical for the management of many of the risks in this chapter. However, there are significant policy gaps in harmonising development, migration and food policies; and in strategically producing and using knowledge and data.

Table 7.1 lists the key risks/opportunities and urgency scores identified for this chapter. More action is needed to:

- **Manage the risks to UK food prices and trade from climate impacts overseas (It1 and It3).** While the absolute availability of food is unlikely to be an issue for the UK as a whole in the future, UK food prices have been, and are likely to be, affected by extreme weather events overseas. Price increases disproportionately affect lower income households, as well as sensitive businesses. Managing the risk to food prices is likely to require strategic, national coordination and planning to manage the resilience of the UK food system, encompassing domestic and international production and trade. There is currently no Government strategy encompassing domestic and international food systems and no overarching role coordinating expertise and actions from the large range of government departments (BIS, DECC, DFID, FCO, FSA, DoH, etc.), academia and industry required to ensure systemic food system resilience.
- **Foster adaptation to climate change outside the UK (It1-It6).** This includes the coordination of development assistance with the EU to reduce risks of migration and conflict in other regions; the development of common strategies and harmonised policies for biosecurity risks; providing assistance to people displaced due to weather-related extremes in their home countries; and on agreed policies with the EU on variations in food availability and price spikes in global food commodities.

Table 7.1. International risks and urgency scores

Risk/opportunity (relevant section(s) of chapter)	More action needed	Research priority	Sustain current action	Watching brief	Rationale for score
It1: Risks from weather-related shocks to international food production and trade (7.2)	UK				At the present, there is no co-ordinated national approach to ensure the resilience of the UK food system. Coordinated approaches require broad participation across policy, industry and research.
It2: Imported food safety risks (7.2)		UK			There is a gap in surveillance systems to monitor food safety at source and through complex international supply chains.
It3: Risks and opportunities from long-term, climate-related changes in global food production (7.2)		UK			The UK may increase its comparative advantage in specific areas of agricultural production in the future. Trends in global agricultural production and consumption need further monitoring and assessment.

It4: Risks to the UK from climate-related international human displacements (7.3)	UK				A more proactive strategy to work in partnership with other countries is needed to provide rapid legal and basic assistance to migrants and to build long-term resilience in exposed regions. Otherwise overseas development efforts will increasingly be diverted to provide humanitarian (i.e. emergency) aid.
It5: Risks to the UK from international violent conflict (7.4)		UK			Further evidence is needed to understand the appropriate balance between long-term development aid (resilience building, disaster risk reduction, state stability) and responsive interventions (peace-keeping, humanitarian aid).
It6: Risks to international law and governance (7.4)		UK			There is a lack of systematic monitoring and strategic planning to address the potential for breakdown in foreign national and international governance and inter-state rivalry, caused by shortages in resources that are sensitive to climate change.
It7: Opportunities from changes in international trade routes (7.4)				UK	Potential changes in trade routes are already being assessed and the issue should continue to be monitored.

Food system resilience (It1, It2, It3)

The absolute availability of food is not likely to be an issue for the UK as a whole as a consequence of climate change. However, as the international food system becomes more vulnerable, food prices in the UK could become more liable to price spikes. This would create risks for households and farmers by impacting on their ability to purchase basic goods and livestock feed, respectively.

A resilient food system ensures that safe and nutritious food is available and affordable. The UK food system encompasses domestic food production (see Chapter 3) and international imports of raw and processed food, including livestock feed. Adaptation efforts focused on the UK's domestic production of food will have only marginal success because of the global interconnected nature of food systems, and the current pressures on domestic resources such as water and soils (see Chapter 3).

The UK food system is affected by short-term climate shocks disrupting production and supply chains, mainly through price spikes (It1). The impact of future global production shocks on the UK will depend on many internal and external factors, including UK and foreign government responses, which have the potential to offset or amplify risk. The UK farming industry and lower income households are particularly vulnerable to shocks. Current evidence and past events suggest that the market is not likely to adapt without affecting UK businesses and consumers negatively in the process. There is currently no

Government food security strategy encompassing domestic and international food systems; and no organisation has overarching responsibility for ensuring UK food security.

Direct impacts to food safety through contamination or substitution of imports can also occur (It2). Changes in climate and geopolitics, coupled with the complex and international nature of supply chains, mean that addressing food safety through monitoring points of entry alone is unlikely to be an effective strategy.

Longer-term threats to the UK food system (It3) arise through changes in the global distribution of agricultural produce and associated trade disruption, which are only partially predictable. Global changes in agricultural production could be offset, for example, by increases in production in specific geographical areas, but would be subject to substantial investments in infrastructure and trade-offs in water resources. The impact of long-term changes also depends on other factors such as changes in population geography and consumption.

Addressing the UK-facing risks posed by climate change to international food systems would increase the country's resilience to exogenous economic and political shocks, as well as bringing sustainability and health co-benefits. It would also help address the risks of increased overseas conflict, migration and geopolitical instability posed by climate change. The UK is well-positioned to be a global leader in strategic long-term thinking on international dimensions of resilience, sustainability and risk reduction. The business case for action on climate change is increasingly recognised by the private sector. There is a significant opportunity to use adaptation to climate change as a catalyst for actions to improve food system functioning, and increase systemic resilience.

Displacement and migration (It4)

The principal, immediate implication for the UK of populations around the world displaced because of climate change impacts is increased demand for humanitarian assistance. There are longer term consequences of political instability and economic changes associated with populations movements globally. Policy intervention is required to increase cooperation with EU states on migration and build mechanisms to facilitate assistance, settlement or return of displaced populations.

Climate change impacts around the world are likely to lead to the movement of populations impacted by extreme weather events, and ultimately to changes to the geography of economic activity and settlement patterns. In the future, significant unplanned migration flows will be more likely as a result of extreme weather events. Weather-related displacement of people from their homes is, most often, of short duration and short distance. The UK is potentially less susceptible to inward international migration flows than other countries due to its location, although it is dependent on EU migration policies that regulate migration flows. But displacement has significant human and economic costs. It can also induce unplanned, permanent migrations in some cases. The current gap in policies and formal mechanisms (the so-called 'protection gap') leaves migrants in need of legal recognition, primary assistance, safe relocation or return. Displacements affect the UK by increasing demand for humanitarian assistance and affecting UK economic interests abroad. They also impact on other geopolitical risks such as conflict.

Geopolitical risks (It5, It6)

Projections suggest that the demand for humanitarian assistance, partly due to climate change, will increase significantly in the coming decades, challenging the balance between meeting short-term demand and building long-term resilience in disaster-prone regions. Research is needed to understand the impact of existing funding mechanisms in building long-term resilience and stability.

Political tensions between states, the threat of violent conflict and the need for international co-operation represent an emerging set of risks for the UK that climate change might exacerbate.

The impacts of climate change are highlighted in many scientific assessments as threat multipliers in already fragile states and regions through increasing stress on governance structures and resource availability, including water. Many regions currently or previously in conflict have low adaptive capacity to the future impacts of climate change, which amplifies and perpetuates conflict risks. The resources required to build long-term state stability and support sustainable development might be challenged by the potential shorter-term need to increase deployments for responding to humanitarian crises, for conflict intervention and/or peace-keeping (It5).

Climate change will also impact on shared natural resources and, as a consequence, the relations between states, particularly international co-operation on shared water resources. The impacts of climate change could increase the risk of revising established principles of international law and governance. The capacity of current conflict resolution mechanisms may also be challenged. A breakdown of state structures could also lead to greater insecurity for trade and transport with implications for UK economic interests (It6). Risks to the UK would be through spill-over effects from increased political tension or, in extreme circumstances, conflict between states.

International co-operation is also required to avoid the risks of transmission of emergent diseases to the UK and other threats to biosecurity (see Chapter 5).

Box 7.1. Comparison with UK Climate Change Risk Assessment 2012

The first UK Climate Change Risk Assessment did not explicitly address international dimensions of climate change in its key findings, but was complemented by a separate report, 'The International Dimensions of Climate Change' (Foresight Report, 2011a). The Foresight report highlighted that the global food system is failing in both its current ability to deliver food security, and longer-term sustainability. It also highlighted multiple threats that are converging on the food system, including climate change, population growth and the availability of land, energy and water. In common with this chapter, the Foresight report highlighted the need for co-ordinated policies across different Government departments and policy arenas, as well as the need for greater international cooperation. Research and analysis since 2011 has highlighted the importance of systemic food system resilience, leading to the following key differences between the Foresight report and this updated risk assessment:

- This chapter goes further than the Foresight report in its recognition of policy gaps.
- This chapter summarises the more recent evidence published since 2012, for example, the results from the AVOID project on price volatility (West et al., 2015), recent studies from Lloyds (Lloyds, 2015) and FCO (King et al., 2015) on 'climate shocks' and a PwC study on international climate change impacts to the UK (PricewaterhouseCoopers, 2013). It also includes a broader discussion of conflict and migration risks.
- This chapter includes a comprehensive assessment of risks related to migration flows globally that were highlighted in a separate Foresight study on Migration and Global Environmental Change (Foresight, 2011b).
- This chapter assesses the uncertainty surrounding geopolitical risks that are exacerbated by climate change, including the demand for humanitarian assistance, global conflict risks, and the biosecurity dimensions of disease risks. These have previously been addressed by separate government reviews, such as the Ashdown Review for DfID (Ashdown, 2011) on humanitarian assistance.

7.1 Context

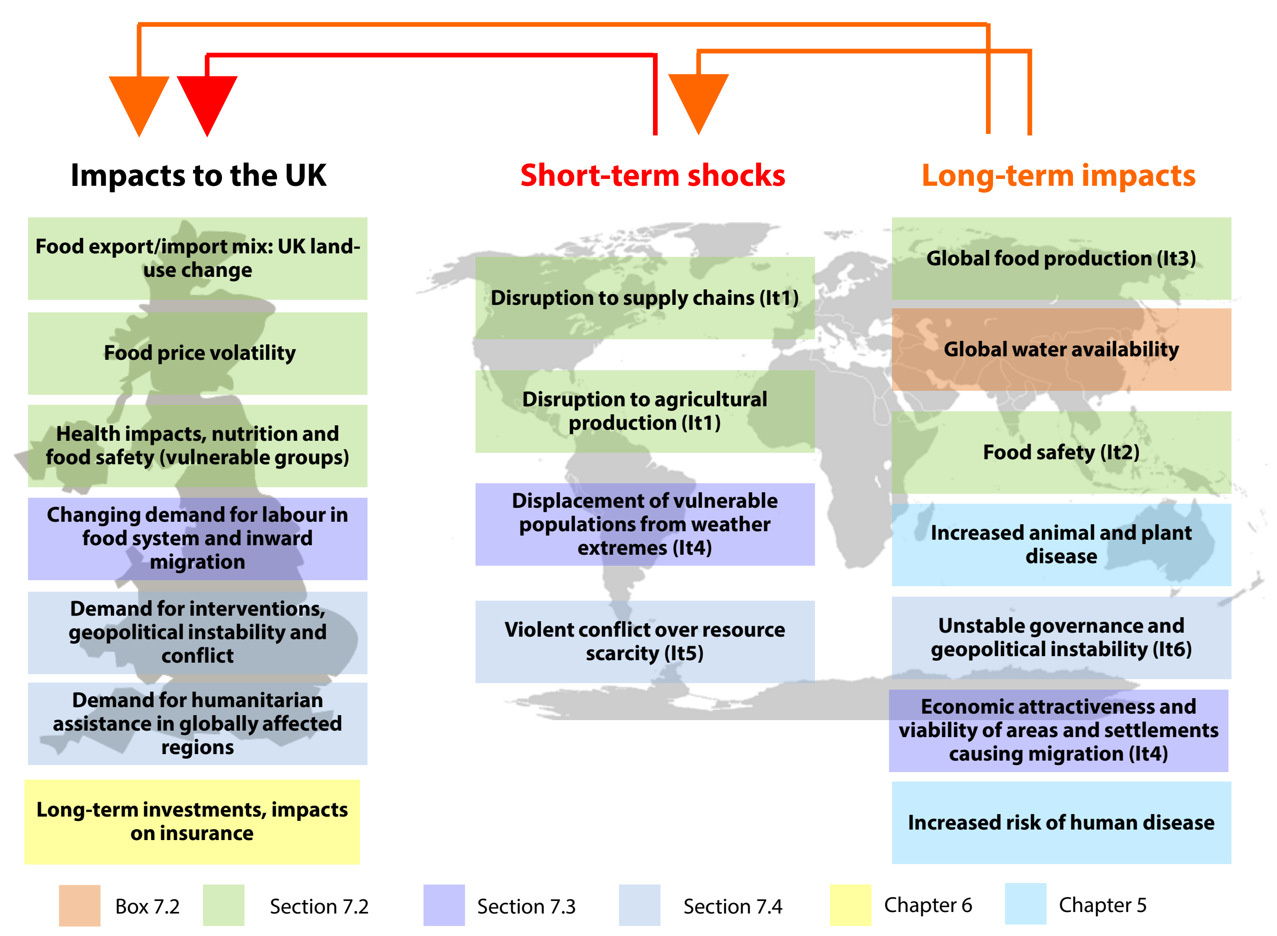
This chapter examines some of the risks and opportunities for the UK from the observed and projected impacts of climate change globally. The interactions between global climate and the UK arise through:

- interactions between markets and economic interests;
- the flow of goods, services and people between the UK and the rest of the world, and
- the placement of the UK within the EU and international political system, including its responsibilities and cultural ties to other parts of the world.

The assessment in this chapter summarises the potential risks and opportunities in three of the four international dimensions that represent the UK's principal landscape of risk: food systems, migration and displacement risks, and broader geopolitical dimensions. A fourth dimension is the risk to international, non-food supply chains. This is discussed in Chapter 6.

In this assessment we identify transmission mechanisms that transfer these global risks into meaningful risks or opportunities for the UK (Figure 7.1).

Figure 7.1. Interactions between food system, migration and geopolitical risks/opportunities for the UK



Source: CCRA authors.

The dimensions of international risk and opportunity are discussed in the central sections of this chapter: 7.2 for food systems, 7.3 for migration and 7.4 for other geopolitical risks/opportunities. In each of these sections we consider:

I. **Current policy frameworks**, in order to understand the current way that risks or opportunities may be managed.

II. **Current risks and opportunities**, describing current international climate and non-climate drivers, global impacts and the transmission mechanisms to the UK.

III. **Future risks and opportunities**, through analysing future dimensions. While there is a significant evidence base in each of these areas, there is also significant uncertainty due to compounding factors and long chains of cause and effect between climate change and the resulting environmental, social and political outcomes. The timing, and in many cases precise nature, of the impacts identified are often difficult to determine. There is a range of interconnected endogenous and exogenous factors that act across borders to determine outcomes. However, this does not prevent robust identification of key risks, some of which are already significant in magnitude. All other things being equal, the greater the extent of climate change, the sooner the risks manifest and the greater their magnitude (King et al., 2015). As such, whether or not these risks become reality is not contingent on specific climate scenarios.

IV. **Adaptation shortfalls** that prevent these risks from being managed, as a result of current policies being absent or insufficient, or markets and actors failing to achieve autonomous adaptation.

The evidence presented in this chapter has been used to determine the urgency of further action for the next round of national adaptation plans and programmes (see Synthesis Report appendix).

Water security in other countries is not considered to be a separate international risk as international water security issues do not affect the UK directly, but operate through other risks (Box 7.2).

Box 7.2. Global water security and risks to the UK

Climate change impacts on global water security

Water security is made up of diverse elements such as appropriate water availability to sustain human needs; sustainability of water availability and supply; and absence of human vulnerability to hydro-meteorological hazards (Cook and Bakker, 2012). Climate change will have far reaching consequences across all of these elements. Direct impacts include the influence that climate change has on the hydrological cycle and water resources. Shifts in water flows in major trans-boundary river basins threaten the stability and availability of water supplies. Changing patterns of extremes will affect flood risk to individuals and communities with consequences for wellbeing. Other climate change impacts on water security include the redistribution of agricultural potential, affecting global food production and trade; conflicting demands for water between rural agricultural and urban areas; and rivalry between countries for shared water resources.

Globally, changes in the hydrological cycle will alter water availability for irrigation, something that is not accounted for in many crop yield assessments. For a global warming of 2°C above pre-industrial levels, global hydrological ensemble models show 10 - 30% reductions in mean streamflow across western and southern Brazil, parts of the south and south-east of the United States, and much of

Box 7.2. Global water security and risks to the UK

western Europe (Schewe et al., 2014). All of these regions export food to the UK. However, most hydrological models do not incorporate the effect that increased CO_2 has on water-use efficiency, which can result in increased runoff and irrigation water availability. For example, Elliott and colleagues (2014) found that, in currently irrigated areas, the need for irrigation could fall by 8 – 15% due to the increase in water-use efficiency associated with rising ambient CO_2. However, this gain from ambient CO_2 would be offset by changes in both water supply and demand globally. The same study has concluded that overall, the global impacts of climate change on streamflow could significantly impact the supply of irrigation water. Limited freshwater availability in heavily irrigated regions could mean that 20 – 60 million hectares of previously irrigated cropland would no longer be irrigated (Elliott et al., 2014). This corresponds to about 6 - 20% of the world's irrigated area in 2006.[1] The potential global limit on viable agricultural area could be offset by increases in specific areas brought under irrigation (e.g. Europe and parts of the US), but only with substantial investments in infrastructure and potential trade-offs with other water uses (for example, for the environment).

Hotspots of current and future water insecurity are identified in all world regions. The impacts of climate change on transboundary rivers draining the Himalayan region, for example, have implications for large populations who are dependent on irrigation for agricultural livelihoods and employment. Evidence suggests that the Brahmaputra river basin (crossing China, Bangladesh and India) and Indus river basin (crossing Bangladesh, Pakistan and China) are the most likely to experience reductions in streamflow. Projections for the 2050s show that changes will also have substantial consequences for food security (Immerzeel et al., 2011). The crucial determinants will be how the Asian monsoon system evolves in a changing climate (Turner and Anamalai, 2012), and the degree of effective management of increasing competition for water as regional demand rises rapidly in the food, energy and water sectors (Godfray et al., 2010). Changes in demand for water at the regional scale, and changes in land and water management, could have a profound impact on availability. Global groundwater depletion more than doubled between 1960 and 2000, equalling about 40% of the global yearly groundwater abstraction (Wada et al., 2000).

Impacts in the UK

The consequences of international water security issues are not direct, as water directly consumed, processed and used in the UK comes almost exclusively from domestic water sources (see Chapter 4). However, the UK uses water resources from around the globe in part via imported food (It1), which itself makes up half the food retailed in the UK. Internationally sourced virtual, or embedded, water resources make up at least half the agricultural water footprint of the UK (GFS, 2015b). Longer-term climate change affecting the water cycle could impact on global food production (It3). Embedded water is also, in effect, imported via goods and services that are produced using hydroelectric energy (see Chapter 6).

There is potential for disputes over water between states sharing the world's 276 transboundary river basins, if rates of climate change in the future exceed the capacity to adapt to the change (Milman et al., 2013; Wolf, 2009). Rates of change are particularly important in relation to the risk of conflict (De Stefano et al., 2012). Historically, disputes over water alone have not directly led to violent conflict (Wolf, 1998), although, in areas with pre-existing political tensions or high water scarcity relative to demand, reductions in water availability could escalate conflict potential (It5). For example, in a 2°C warming scenario, global hydrological ensemble models show reductions in streamflow of 10 to 50% across North Africa, the Mediterranean and the Middle East (Schewe et al., 2014a). All of these areas

[1] http://www.fao.org/fileadmin/user_upload/newsroom/docs/en-solaw-facts_1.pdf

Box 7.2. Global water security and risks to the UK

already experience relatively low per capita water availability, rising consumption and in some cases ongoing political tensions. Plans throughout the world to deal with increased climate variability and changes in overall water resource availability are presently focused on expanding water storage infrastructure like dams on major rivers. Such infrastructure development has potentially negative consequences in downstream areas, including other countries.

There are a number of international treaties and arbitration institutions for some major transboundary basins that have been somewhat effective to date in managing relations between countries (Wolf, 2009; Milman et al., 2013). Yet modelled and projected climatic change and planned infrastructure developments have the potential to destabilise current co-operation (It6, Section 7.4).

Source: CCRA authors.

7.2 Dimension 1: Food systems

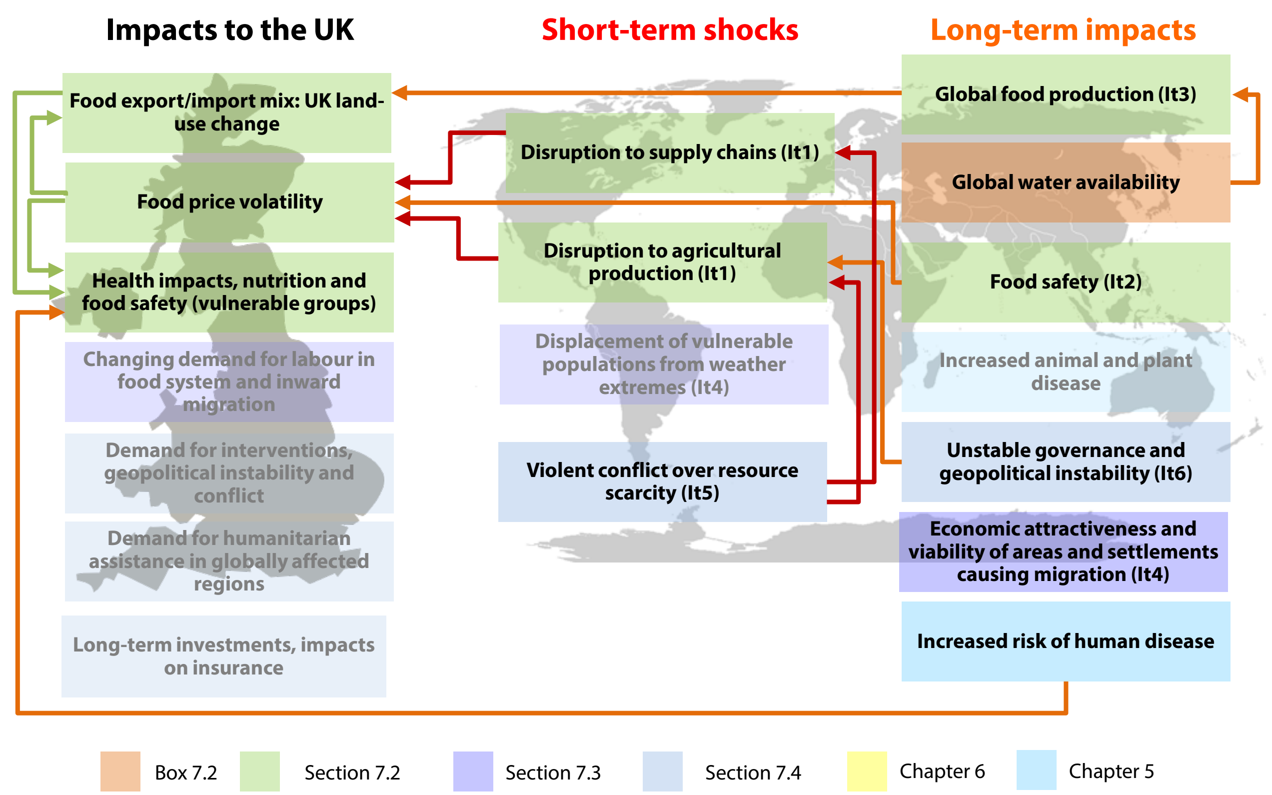
Climate change could undermine the resilience of the UK food system by affecting affordability, markets, trade and safety. This section summarises the current evidence on risks to the UK food system from international climate change.

The concept of food security is important for understanding food systems. The Food and Agriculture Organization (FAO) defines food security as being 'when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO, 1996). The FAO identifies four pillars: availability, which is strongly related to production; access, which includes affordability; utilisation, which describes the safety and nutritional value of food; and stability, which distinguishes chronic food insecurity from shorter periods of difficulty. Food security, therefore, necessarily encompasses nutrition and safety (not just calories), stability of prices and social protection for the poor.

While the term 'food insecurity' is often reserved for instances where access to food is a major challenge, the definition above makes it clear that it can apply in a range of other contexts. Food availability, affordability, safety and trade are all relevant aspects of food security for the UK. In order to avoid misconceptions, the term 'food systems' is often used in this chapter where the term 'food security' might equally be applied. This choice of wording emphasises that the key issue surrounding food in the UK is not systemic food insecurity, but rather the need for systemic resilience to international vulnerabilities in the food system (Centeno et al., 2015).

As summarised in Figure 7.2, climate impacts that can potentially undermine the resilience of the UK food system include extreme weather-related impacts on international production and supply chains (It1); impacts to food safety (It2); and long-term climate change impacts on global food production and trade routes (It3, It7). These factors are also influenced by other international stressors discussed in this chapter, particularly violent conflict and state fragility (It4). They manifest as UK risks mainly through price spikes, which affect availability and affordability; trade, including balance between imports, exports and domestic production; and health impacts, including both nutrition and food safety. These impacts are interconnected.

Figure 7.2. Climate drivers of global food-related risks and impacts to the UK



Source: CCRA authors.

These risks are driven by changes in both the average climate and extreme events, which lead to long-term trends in a number of metrics and weather-related shocks, respectively (Table 7.2). These changes will vary geographically and the precise patterns of change are uncertain, as are the societal responses to the changes. It is therefore not possible to predict changes in UK imports, exports or in sustainable practices. However, links between risks and the leverage points for reducing risk are known.

Table 7.2. Food-related risks and associated climate drivers

	Weather-related events	Long-term climate changes
Production shocks and changes	Production shocks	Global changes in food production
	Increased/decreased exports from the UK	
	Increased/decreased sustainability of agriculture globally and in the UK	
Disruption to supply chains	Impacts on infrastructure such as port closures, flooding of storage facilities etc.	Food safety New trade routes
Changing food composition	Food safety, nutrition	

Source: CCRA authors.

It1: Risks to the UK food system from weather-related shocks to international food production and trade

As an economically developed nation, the UK population is unlikely to suffer a prolonged lack of access to sufficient food now or in the future as a consequence of climate change. However in 2012/13, the Trussell Trust reported that 350,000 people accessed food aid in the UK. Cooper and Dumpleton (2013) estimate that the annual number of people accessing food aid may be over 0.5 million people and at least 4 million people do not have access to a healthy diet[2] (Cooper and Dumpleton, 2013). For these people, lack of access to nutritious food because of unaffordability can prevent them from achieving balanced diet.

The risk to people from decreased food affordability has been evident in the UK during recent climate-related food price spikes. For example, due to a number of events in 2007/08 there were marked shifts in prices and a subsequent reduction in the purchasing of nutritious foods such as fresh fruit and vegetables, especially in the lowest income deciles (Defra, 2012a). The risks to the UK from reduced affordability of food are mediated through international availability and supply chains which are at risk from climate change (Risks It1 and It3). These risks are detailed in Section 7.2.2, with further information on food price spikes described in Annex A7.2.

Current measures to manage the risk of price spikes in the UK include trade agreements and monitoring of price spikes. The Government does not actively intervene to manage price fluctuations. However, markets may not be able to function well under stress from increased frequency and scale of extreme events, and gradual long term climate changes. There is a growing awareness of this issue in the food retail sector. There is now significant activity underway to identify risks of climate-related interruptions to supply chains, but the risk is projected to increase over the coming decades (Section 7.2.2).

It2 Imported food safety risks due to food-borne disease, contamination and toxicity

In contrast to availability and affordability, food safety issues could affect all income groups. The risk is driven by changes in food composition through diseases affecting food products (e.g. avian flu) or microbial contamination and toxicity. Changes in the availability of agricultural products will also likely lead to substitution of ingredients (see Section 7.2.3). Given the volume of food imports, quality assurance schemes of food importers are a key element in managing food safety. The existing risks to UK food safety from imports are of relatively low likelihood, although with high potential impact. In the longer term, new food safety risks are likely to emerge as a result of the climate-induced geographical spread of diseases and microbial toxins. The complex nature of international food supply chains, coupled with the growing nature of this risk (Section 7.2.3) necessitates monitoring of both UK food imports over time and the potential for emerging threats beyond UK borders.

It3, It7 Risks and opportunities derived from long-term changes in global food production patterns

A longer-term threat to UK food availability comes from declining yields and the potential for geographical changes in food production (It3, Section 7.2.3). Coupled with increases in demand

[2] A 'healthy diet' is defined as containing specific caloric and nutritional contents, as well as sources of these calories (e.g. proportions of fruits, vegetables, legumes etc.). See http://www.who.int/mediacentre/factsheets/fs394/en/

driven by population growth and changing diets, including increased consumption of meat and processed food, agricultural expansion worldwide is likely to be required if future demand is to be met. This in turn would amplify competition for resources and increase greenhouse gas emissions.

If climate change makes UK agriculture comparatively more competitive, the market may respond by intensifying agriculture domestically. This has the potential for environmentally unsustainable agri-business practices and longer-term depletion of the resource base, especially natural assets like soils and their associated ecosystem services. In fact, current downward trends in the condition of these natural assets may limit the capacity to produce more food in the UK in the future (see Chapter 3). This could lead to greater dependence on imports.

Predicting shifts in food production is difficult because the extent to which future extreme events could hamper domestic and international production is unclear ; and there is no quantification of the climate and environmental thresholds (commonly referred as "tipping points") that could have irreversible impacts for the UK and international natural assets (Chapter 3) .Thus it is currently impossible to predict what the global changes in food production will be, or what their impacts on the UK will be. Increased competitiveness and increased dependency on imports are both possible, and impacts may be different for different food groups.

Climate change could give rise to non-food agricultural export opportunities for the UK. The UK is in a good position to support adaptation and agriculture overseas. The principal business opportunities in support of global agriculture include agrichemicals, biotech and agri-informatics to be used in, for example, precision farming, climate risk management tools and expert advice, and transport (see also Chapter 6). The UK is also well-positioned to make contributions to overseas adaptation through knowhow, for example, in water resources, healthcare and infrastructure. Some opportunities also arise for business, such as those from Arctic ice melt (see Box 7.3, It7).

There is a role for UK businesses to increase the sustainability of their operations regardless of climate change. As UK business gives increasing attention to climate change, it is likely to find significant opportunities for improving food systems, reducing costs and responding to demands from consumers more aware of climate change and other sustainability issues related to food. A growing number of food companies are already aware of the clear business case for more sustainable practices throughout their supply chains. Demand-side measures to guide nutrition and health can also lead to greater sustainability as healthier eating makes more effective use of available food (e.g. reducing consumption of meat, especially in processed meat diets). The increase in sustainable practices, including reducing waste throughout the supply chain, will also support longer-term food system stability and increase resilience to climate change.

7.2.1 UK food system resilience and food safety policy

As the definition of food security includes access to food for a healthy life, the resilience of the UK food system covers policy domains across a range of UK government departments including:

- the Department for Environment, Food and Rural Affairs (Defra) for food supply;
- the Department of Health (DoH) for public health, diet and nutrition, and food-related illnesses such as diabetes;

- the Food Standards Agency (FSA) and Food Standards Scotland (FSS) for food safety and consumers' interests in relation to food;
- the Treasury, Defra and Department for Business, Innovation and Skills (BIS) for international dimensions and interests in trade;
- the Department for International Development (DfID) for food security in other countries, and
- the Foreign and Commonwealth Office (FCO) and the Ministry of Defence (MoD) for international dialogue and national security.

The main policies related to UK food system resilience are summarised in Annex 7.A.

Although Defra's new food security strategy has not yet been published (as of 17 June 2016), the Government response (Defra, 2015a) to the Environment, Food and Rural Affairs (EFRA) committee report on food security (EFRA, 2014) states that the objectives of the Government food security strategy are:

1. UK food security built on access to a wide variety of markets including domestic, the EU and an open, rules-based world trading system.
2. The importance of sustainable intensification of UK agriculture.
3. Making the most of our productivity potential through the agri-tech strategy (Defra, 2015a).

Food production and manufacturing are devolved policy areas in relation to domestic production, while overarching goals on UK-wide food security in the devolved administrations are in line with Defra objectives or not stated. National food strategies are mostly directed at domestic production. For example, 'Food for Wales, Food from Wales 2010/2020' (WAG, 2010) is a ten year policy statement that sets out the policy direction outlined in 'Towards Sustainable Growth: An Action Plan for the Food and Drink Industry 2014 – 2020'. The strategy recognises the integration of the Welsh food system into UK and European systems and the influence on it from the wider global context. The Northern Ireland strategy (Agri-Food Strategy Board, 2013) adopts similar objectives to those delineated by the Government, but includes an explicit recognition of the role of Government by calling for greater Government intervention in areas such as the identification of best practice for efficient production in relevant sectors and the development of strategic regional land management policies to determine the most productive use of land. Both the Northern Ireland and Wales strategies recognise the potential for linking food security and health.

The Food Standards Agency (FSA) is responsible for developing and implementing food safety policy in England, Wales and Northern Ireland and is the UK Competent Authority with respect to EU law on food safety. Food Standards Scotland is responsible for food safety (and nutrition) policy in Scotland. Policies are similar around the UK as they reflect EU frameworks. The international dimensions of risk for food safety are mostly due to contamination of food by chemicals or pathogens, or substitution of expensive food for cheaper alternatives (such as horse for beef). This latter risk is often associated with differential price rises, which may reflect production shocks. The main legislation in England covering the import of food containing animal products is the Trade in Animals and Related Products (TARP) Regulations 2011. Scotland, Wales and Northern Ireland have their own very similar regulations. The regulations establish controls on food imported from countries outside the EU. The EU Official Controls Regulation 882/2004 and The Official Feed and Food Controls (England) Regulations 2009 (HM Government, 2009) and the equivalent in Scotland, Wales and Northern Ireland are the main legal instruments governing the control of food not-of-animal-origin entering the UK from non-EU countries. Food imported from non-EU countries must also comply with the requirements of the Food Hygiene Regulations (EC Regulation 852/2004). The duties of port health authorities are key to the international dimensions of food risk. These duties include ensuring that only products that are safe to eat enter the food chain; safeguarding of animal and public health; and checking compliance with EU rules and international trading standards.[3]

7.2.2 Current risks and opportunities for food systems

Risks to the UK food system from weather-related shocks to international food production (It1)

The global food system has multiple interdependencies:

- For major agricultural commodities, a significant proportion of total global production is now traded internationally (Liapis, 2012). This has positive impacts, including on diversification, trade and world commodity prices, which have been low in real terms prior to the price shocks of the late 2000s.[4] At the same time, the increasing global interconnectedness of global food systems via trade increases the susceptibility of food supplies to production or price shocks, or policy shocks such as multiple trade embargoes (ibid; Foti et al., 2013).
- Imports constitute the majority of domestic consumption for approximately 85% of countries, with significant interdependence in their food supply (Ercsey-Ravasz et al., 2012; Fader et al., 2013). In 2014, 22 countries (included UK) accounted for 90% of the supply of all UK food, valued on a raw food basis (Defra, 2015b).
- For example, around half the farm-gate value of unprocessed food in the UK is imported. The UK's principal trading partner is the EU (27%) (Defra, 2015b), but imports arrive from 168 countries in total (Defra, 2012a). Meat, dairy and eggs are mainly supplied domestically (84% and 86% respectively) (Defra, 2015b).
- Some key food staples come from a small number of specialised countries. For example, 34% of processed and unprocessed cereals are imported from 11 countries (Defra, 2015a). For maize, just over 27% of the UK import comes from China, 17% from France, 15% from the US and 12% from Brazil. China is the main producer of rice for the UK (about 54%), followed by India (12%) and Thailand (10%). Around 42% of UK soy comes from Brazil and 32% from Argentina (West et al., 2015). This concentration in production is one of the key vulnerabilities in food markets (Abson et al., 2013).

In recent decades, there has been about a 1% chance per year of losing approximately 10% of global calories produced around the world (GFS, 2015a). Globally, climate events have caused major production losses in the past: 8 of the 20 years from 1993 to 2012 showed a globally significant major production loss associated with one or more climate extremes (Porter et al., 2014). For example, back-to-back droughts in Australia in 2006 and 2007 reduced grain exports by an average of 9.2 million tons per year (about half of the annual production) compared to 2005, and poor crops in the EU and Ukraine led to export reductions of 10 million tons in 2007

[3] https://www.gov.uk/port-health-authorities-monitoring-of-food-imports
[4] http://www.fao.org/docrep/014/i2330e/i2330e03.pdf

(Mitchell, 2008). A number of the production shocks during 1993 – 2012 suggest some underlying climate trends (Porter et al., 2014). While predictions of the frequency of extreme events are inherently difficult to make, the trend towards increasing occurrences, and the attribution of that trend to anthropogenic climate change, is clear (e.g. Hansen et al., 2012). The number of extreme events (heatwaves, droughts, flooding and other climate-related hazards) has increased over the last decade (WMO, 2013). Otto et al. (2012) examined the Russian heat wave of 2010, finding that in the 1960s, such an event would be expected approximately every 99 years (i.e. an annual risk of 1%), whereas in the first decade of the 21st century this would be expected to occur every 33 years (i.e. an annual risk of 3%).

Since the 1990s, climate extremes in major growing regions have often been followed by spikes in global food prices, leading the Intergovernmental Panel on Climate Change (IPCC) (Porter et al., 2014) to conclude that prices may have become more sensitive to weather-related food shortfalls in recent years. The relationship between harvest failures and food prices is a complex one, as it is also influenced by market mechanisms, export taxes or bans and increasing demand for biofuel (Piesse and Thirtle, 2009; Hernandez et al., 2010; Porter et al., 2014; see also Chapter 3). Despite this complexity, the impact of extreme climate events can clearly be amplified by markets and associated factors (GFS, 2015a), such that a significant impact on world prices can result from relatively modest shortfalls in global production (Wright, 2011).

The IPCC assessment (Porter et al., 2014) concluded that in this new era where food prices and oil prices are more closely linked, market and policy responses to production shocks can lead to price volatility. The Global Food Security report (GFS, 2015a) went further, showing that the vulnerability of the global food system to production shocks caused by extreme weather is already significant and is growing. The report also identified a risk of multiple simultaneous production disruptions in key producing areas (breadbaskets), based on a plausible combination of historical production shocks. Analysis of the implications of such multiple breadbasket failures demonstrated that widespread political, social and economic disruption across the globe is likely, including significant impacts on the UK. Multiple interacting factors lead to food price spikes (Annex 7.C), so that the role of climate risk is difficult to quantify.

The characteristics of global agricultural trade are such that it can amplify the underlying climate risk. There are three aspects to this:

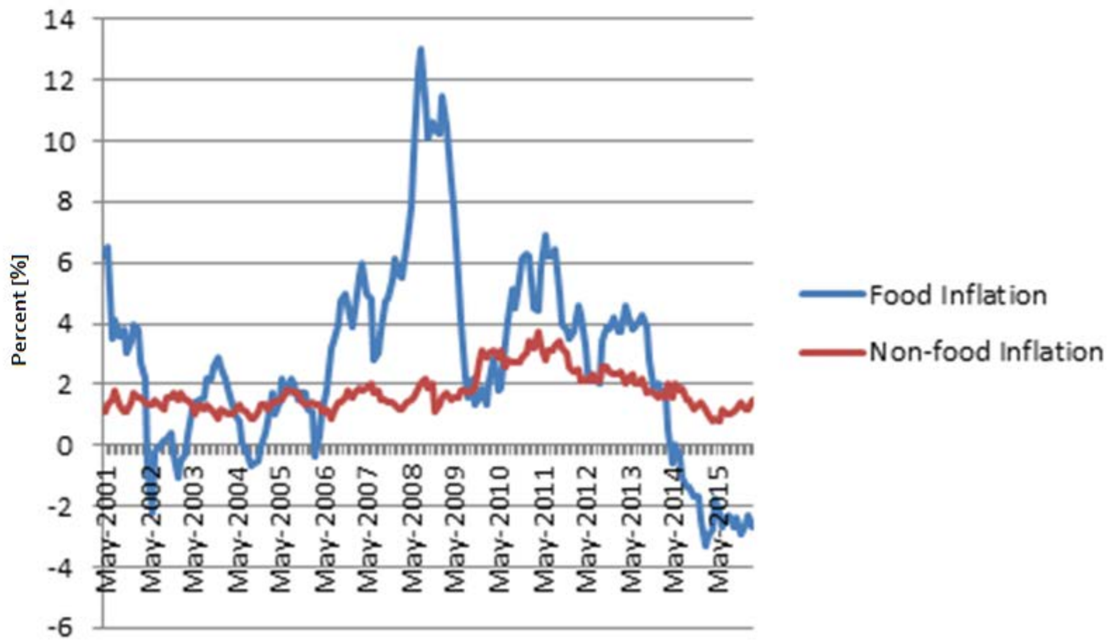
- First, countries can direct domestic production to domestic consumption, and this has a tendency to make world markets relatively volatile because, if shocks occur, exports are more likely to be affected than imports.
- Second, agricultural production of key staples tends to be highly concentrated. The top five wheat exporters accounted for around 80% of total world wheat exports in 1995 with the US accounting for 32%, Canada 17%, France 16%, Australia 8% and Argentina 7% (Annex 7.B). The import side is also highly concentrated.
- Third, the structure of world agricultural markets has changed in recent years, for example Russia and the Ukraine have increased their share of world exports. Some of these changes have made the market more vulnerable to price spikes (see Annex 7.C).

Climate impacts on global food production are thus likely be transmitted to the UK through food prices, especially because UK food prices are particularly sensitive to events on world food markets (Lloyd et al., 2015). Volatility in UK food inflation has far exceeded that of non-food inflation over the last 15 years. The experience of food inflation in the UK is shown in Figure 7.3 with recent spikes coinciding with the decline in global agricultural exports as noted above. The exposure to food inflation pressures in the UK tends to be higher than that of many EU countries, reflecting the open nature of the UK economy (ibid). This is shown in Figure 7.4, which highlights the average experience of food inflation relative to the average of non-food inflation over the 2000 – 2014 period in other EU countries. As is evident from the figure, with the exception of Sweden, the UK's relative experience of food inflation has been higher than that of other EU Member States. These data underpin the exposure the UK faces with respect to developments on world markets.

Price spikes have a direct impact on low income households. Increased food prices diminishes the disposable income to spend on other basic goods, such as clothing and education (FAO, 2011; Watkiss et al., 2016); and on food, for the lower income bands (Defra, 2012a).

Crop price spikes also affect animal feed (CERF, 2015). For example, the 2011/2012 US drought contributed to an increase in the price of soya, causing up to an estimated 25% of UK pig farmers leaving the industry by end of 2012 (Benton, 2012). The losses from the 2012 drought have an estimated 20% annual chance of occurrence[5].

Figure 7.3. UK food and non-food inflation (May 2001 – April 2016)

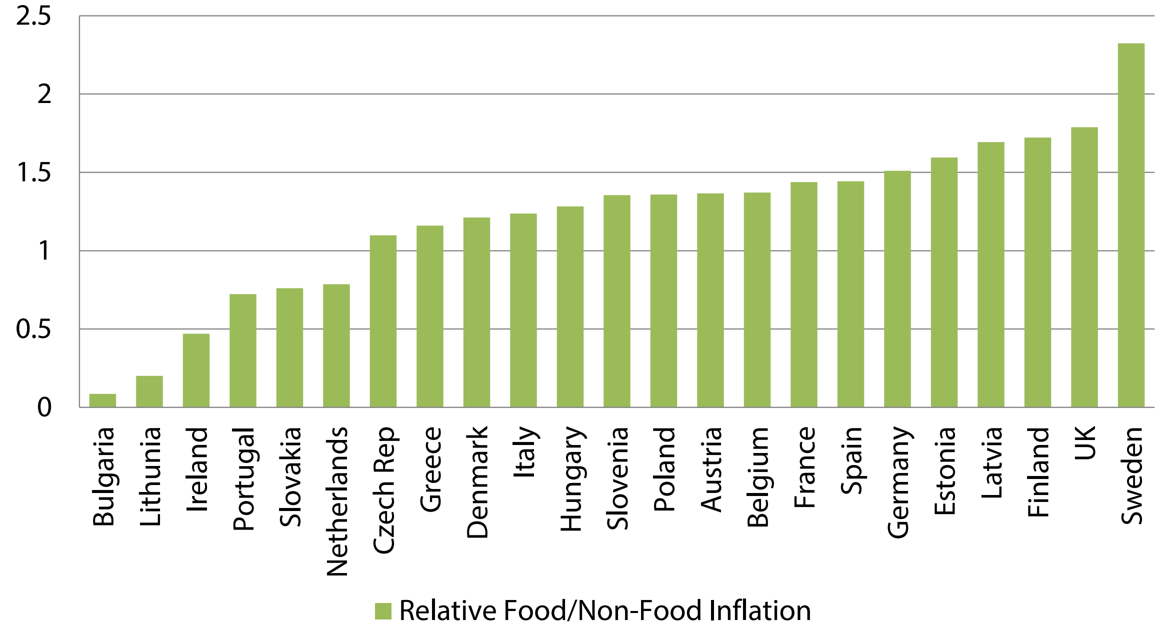


Source: Data up to 2014 are from Lloyd et al. (2015). Date after 2015 are from ONS Consumer Price Index.[6]

5 http://www.air-worldwide.com/Publications/AIR-Currents/2013/The-2012-U-S--Drought-and-What-to-Expect-from-the-2013-Crop-Season/

6 http://www.ons.gov.uk/economy/inflationandpriceindices/bulletins/consumerpriceinflation/apr2016

Figure 7.4. Average ratio of food inflation and non-food inflation across EU Member States, 2000 – 2014



Source: Lloyd et al. (2015).

Considering the range of sources from which the UK imports food, two observations may be made. First, the large range of food sources, and the interconnected nature of markets, means there are few parts of the globe where a production shock would fail to have an impact on the UK. Second, production shocks in the EU are likely to have a particularly significant effect in the UK. For example, in 2003, due to a large-scale heat wave, French maize production fell by nearly one-third (Parry et al., 2007). There were broader impacts of this event in Europe which, in the absence of trade, would have significantly affected food security (Battisti and Naylor, 2009).

In addition to market responses, the impact of extreme climate events on food systems also depends on how governments respond. Production shortfalls are a typical feature of world agricultural markets but trade helps buffer production shortfalls when they arise in specific countries, either by diverting purchases to other sources, or by cutting net imports. Research related to the experience of the commodity crises in 2007 – 2008 and 2011 showed that one of the main contributory factors to the price spikes was how governments responded. In order to soften the domestic impact arising from price rises on world markets, governments used trade policy instruments such as banning exports in order to promote domestic food security. This had the effect of fuelling larger price spikes on world markets. Accounting for potential unilateral government responses is therefore crucial in assessing this risk (Martin and Anderson, 2012).

The UK is now more dependent on food imports than it was in the 1980s (see Annex 7.B), thus linking domestic food supplies to production shocks among the UK's leading trading partners. How the UK's trading partners respond to events on world markets is therefore also important. It is necessary to gauge how leading trading partners, such as Russia and the Ukraine, and Argentina and Brazil, will respond to climate events and price spikes and whether they will always abide by the rules of international trade in such circumstances. In this context, the UK's role in future developments in the EU's Common Agricultural Policy (CAP) and, by extension, developments in the WTO, are important to create the appropriate policy structure to minimise the impact of price shocks and underlying price increases from climate change.

In summary, how production shocks specifically impact on the UK will depend on how they interact with other factors, which have the potential to offset or amplify risk (Annex 7.C). For example, protectionist responses from governments that seek to address domestic issues in the face of production declines may increase price volatility. The UK government has significant influence over these exogenous factors, for example, through anticipating and managing protectionist responses, which highlights the importance of coherent policy making in this area. If markets are working well, climate-induced volatility is likely to be dampened (Puma et al., 2015). But markets alone cannot be relied upon to manage price spikes and volatility, especially as food production has become increasingly susceptible to instability in recent decades (Suweis et al., 2015).

Risks to the UK food system from disrupted international supply chains (It1)

Transport for the majority of agri-food commodities is by sea, since the commodities are relatively low value by density. Globally, 77% of the total value of raw agricultural products is transported by sea, 17% by road, 3% by air and 3% by rail (Cristea et al., 2013). For processed food, it is 56% by sea, 39% by road, 3% by air and 2% by rail. The impacts of severe storms and associated surges on loading and unloading at ports have been identified as a global issue affecting trade routes. Becker et al. (2013); Bailey and Wellesley (in press); and Centeno et al. (2015) highlight that much international trade is channelled through a small number of 'chokepoints' which makes trade highly vulnerable to disruption caused by weather. These include the Panama and Suez canals, which handle around 5% and 15% of global sea-borne trade, and 11% and 26% of global cereals trade, respectively.

Food trade hubs are vulnerable to both the direct impact of extreme weather and indirect impacts via conflict or political instability (risks It5 and It6). If a major hub were to be affected, direct and indirect impacts would combine, producing an increased risk of price spikes (cf. risk It1). For example, sustained and major disruptions to exports from the US or the Black Sea could likely expose UK prices to significant fluctuation, due to the importance of the trade in these regions (Annex 7.C).

In addition to the effect on prices, disruption to international supply chains could affect access to food in the UK. Some specific current and future risks to UK imports of rice and soybean posed by extreme weather were highlighted by Bailey and Wellesley (in press) and are presented in Annex 7.D. There are also numerous potential issues for UK supply chains for specific highly traded foods such as fruit and vegetables. For example, the area of orchard land in the UK fell by nearly a third between 2001 and 2007, and more than two-thirds of the apples consumed in the UK are now imported[7].

More than 90% of UK food imports arrive by sea (Defra, 2012b). A recent study (Achuthan et al., 2015) reviewed the risks associated with storm surges in the east coast ports (Dover to Tyne), which account for 57% of food imports. The report identified a major tidal surge on the east coast as a major potential risk to import capacity. Road and rail also play important roles in food transport (from farm to factory to port in the exporting country). While the distributed nature of

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7 http://www.ifr.ac.uk/science-society/spotlight/apples/

road and rail provide some resilience to trade-flows, there remain considerable climate risks. For example, within the EU (which is the UK's principal trading partner), the EU FP7 WEATHER[8] project estimated that the annual costs of extreme weather on land transport logistics (across all sectors) was €2.5bn. As with maritime infrastructure, there are key pinchpoints where disruption can have major impacts (e.g. routes towards ports, major arterial highways). One of the major constraints on Brazilian soy exports is the transport infrastructure inland of its ports[9].

Food stock levels in the UK have decreased since the new millennium (Annex 7.C), which decreases resilience to supply chain disruption. Food safety (risk It2) and associated consumer mistrust could also be an issue. Finally, there would also be a loss of revenue directly resulting from the disrupted trade.

Imported food safety risks (It2)

Food quality and safety can be directly affected by disease and toxicity. Substitution of one ingredient for another can also generate quality and safety issues. The National Food Crime Unit has published the first Annual Food Crime National Assessment on behalf of the FSA and Food Standards Scotland[10] which identified the UK food system as vulnerable to food crime, with climate-related disruptions playing an increasingly important role. Imported goods vulnerable to food crime include specialised products such as honey and olive oil. Climate change acts as a multiplier on existing quality and safety issues mediated by the supply chain. There are many risks to food safety associated with extreme events:

- Environmental contamination associated with increased flooding, pesticide use, and transmission of disease and toxicity through food (Tirado et al., 2010).
- Interruptions to logistics (Risk It1) can have direct impacts on the availability of food and indirect ones, such as creating opportunities for accidental or deliberate substitution of one ingredient for another, which could have safety risks associated if substitution involves food fraud (Busta and Kennedy, 2011).

  Substitution of ingredients may be transparent and have little impact; or it may act as an incentive for food adulteration and have significant risks for food safety or quality. Substitution is more likely for ingredients with limited supply and strong demand. For example, the two main producers of cocoa are Ghana and Côte d'Ivoire, which together produce 53% of the world's cocoa (Laderach et al., 2013). This can lead to substitution of cocoa with palm oil (section 7.2.3).
- Substitutions may reduce the safety and quality of the final product. The substitution of horse meat for beef that came to light in the UK in 2013 highlights the potential for widespread substitution that may go unnoticed by manufacturers, retailers and the authorities. Another example is the substitution of peanut for cumin, with clear safety implications given the allergenicity of peanuts. For example, India provides around 75% of global cumin production. Production of cumin in Gujarat, the major growing region, was 40% lower in 2014 than in 2013. This reduction was partly due to sowing delays caused by high temperatures and partly due to the low market price in 2014, following a bumper

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8 http://www.weather-project.eu/weather/index.php
9 http://www.bbc.co.uk/news/world-latin-america-22188250
10 https://wwwcumi.food.gov.uk/sites/default/files/fsa-food-crime-assessment-2016.pdf

harvest. Although it is difficult to find a causal relationship between this episode and the recall of cumin in the US,[11] it exemplifies the potential issue.

- Poor storage conditions can expose stored products to microbial contamination. This may be exacerbated by extreme heat or humidity and give rise to significant potential health impacts. For example, studies show that incidence of human *Salmonella* poisoning in Canada and Australia increase with temperature. In Europe, increases of 5 – 10% for each degree temperature rise above 5ºC have been observed, although in the UK total incidence is declining due to better management techniques (see Chapter 5). In south Australia, a doubling of associated mortality rates by 2050 has been predicted (Tirado et al., 2010).
- Some fungi that grow on many crops (e.g. maize, wheat) produce mycotoxins, which can have acute and fatal consequences. Temperature and water stress during crop growth tend to increase mycotoxin incidence (Miraglia et al., 2009). Measuring contamination levels in the food chain is not straightforward. Even relatively small doses with no clinical symptoms are associated with carcinogenic, immunosuppressive and neurotoxic activity (Tirado et al., 2010). Roughly a quarter of the global annual maize crop is contaminated (Vermeulen et al., 2012) and the toxins have been detected in cereal-based foods such as bread, noodles, breakfast cereal and baby food (Chakraborty and Newton, 2011).
- Weather can interrupt the supply chains of goods requiring temperature controlled environments through contamination or spoilage due to goods being exposed to higher temperatures. The largest product recall in US history (3,192 products across more than 200 companies) came from *Salmonella*-contaminated peanuts entering the food chain (Johnson, 2014). While this outbreak was unrelated to weather, it highlights the potential impact of contaminated food within the food chain.

There is some evidence of engagement in adaptation in response to climate-induced food safety issues in the fresh produce sector, such as water control, pesticide management, personal hygiene requirements and (cold) storage control. However, these responses vary among different countries (Kirezieva et al., 2015).

Opportunity: UK expertise and interests in adapting global agriculture to climate change

The above discussion is largely in the context of food imports to the UK. There is also the potential for the UK to export a range of products and services aimed at supporting production overseas. Agrichemicals, biotech and agri-informatics can be used to develop climate-smart technologies (Emberson et al., 2015), as well as drought, heat, pest and disease resistance in crops (Baulcombe et al., 2014). UK business can contribute to the infrastructure and logistics of transport of food abroad (c.f. risk It1), which in turn supports our own food security. Research institutes such as the UK Meteorological Office, commercial weather (agrometeorological and flood) forecasting services, the risk management sector and the emerging expertise in climate resilience services may be able to apply their world-leading expertise to supporting climate risk management in international settings.

The potential for exporting risk management tools goes beyond agriculture to include, for example, water resources, healthcare and infrastructure (PricewaterhouseCoopers, 2013). UK

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[11] http://www.fda.gov/Food/RecallsOutbreaksEmergencies/SafetyAlertsAdvisories/ucm434274.htm#recalledproducts

consultancies, particularly in environmental and engineering, and financial and business services, possess strong expertise and global reach. They are therefore well-placed to contribute to adaptation processes across all sectors (GHK, 2010). This could include commercial services and roles in providing technical assistance to developing countries through international climate finance. It is argued that such companies have skills in many of the key elements required for adaptation, such as linking risk assessments with impact modelling, mapping and scenario building (GHK, 2010). UK consulting firms are already involved in developing activities to provide climate change information services to corporations and public bodies to help them understand climate change risks and to develop adaptation plans (Agrawala et al., 2011). The UK is thus in a good position to respond to increased international demand for insurance and risk-based advisory services. There is also the potential to respond to increased demand for adaptation guidance and technical support through United Nations Framework Convention on Climate Change (UNFCCC) mechanisms, International Climate Funds and other international clients.

This opportunity is discussed in Chapter 6 of this report and therefore not considered further here.

Managing food system risks can improve public health and lead to more sustainable business practices

Many of the actions to improve food system resilience could be tailored to create more sustainable approaches with better health outcomes and should therefore be seen as an opportunity resulting from climate change adaptation. Improvements in food system stability can reduce the risk of climate impacts on prices or availability of food. For example:

- Awareness of healthy eating promotes diets that improve the sustainability of the food system by making more effective use of available food (Soussana, 2014) and by increasing the ratio of vegetables to meat.
- Tackling pre- and post-market food waste, which varies globally between around 10 and 40%, would significantly increase the sustainability and resilience of the food system.
- Improved land use across the EU could reduce the need for net imports (PricewaterhouseCoopers, 2013; Soussana, 2014).

Improvements to food security overseas positively influence other international risks, including conflict and migration. Climate change provides a catalyst for action. While scenarios of potential issues around water, food and energy resources out to 2050 are often grounded on the growing population and associated increase in demand, alternative narratives suggest the potential for a future where food systems are more sustainable (Tomlinson, 2013). Private-sector buy-in for sustainability is key to capitalising on these and other opportunities.

There are several local initiatives to encourage business to improve their knowledge of the food system (for example http://bristolfoodpolicycouncil.org/wp-content/uploads/2012/10/Who-Feeds-Bristol-report.pdf). However, some businesses may lack the necessary information to link climate change for their supply chains, production and distribution networks and to the demand to their products.

Government intervention in this context could include provision of information and decision making tools to increase awareness. One such tool is natural capital accounting which can show impacts and dependencies between natural capital and business over a long time period.

Improving relationships with the suppliers, through providing them with incentives such as long-term contracts, has been shown to be beneficial in helping to capitalise on opportunities for improved public health and food system stability. Agreements between producers and the supply chain to sell goods onto consumers that meet certain attributes (for example goods with high environmental, health or social credentials) are another such mechanism. There are also opportunities to link more sustainable business practices with development and agriculture (both in the UK and overseas) through the use of sustainability standards and certification (e.g. ISO, ecological footprints).

Voluntary standards within a company can also be productive. For example, some major retailers have internal 'sustainability standards', which involve assessment of climate risk, resilience, carbon and water efficiency, and broader sustainability. Major retailers imposing internal standards on producers can have a global impact on the resilience and sustainability of production.

There are likely to be significant trade-offs associated with each of these opportunities. If business is aware of the broader issues of climate and environment that will affect their future profitability, or can see that they gain popular support and market share through their actions on sustainability, they can drive mitigation and adaptation around the world. If businesses fail to see this, in spite of actions to increase awareness, voluntary initiatives, investment incentives etc., then stronger intervention that regulates or incentivises business behaviour (such as caps, trading, taxation on emissions or use of certain raw materials) becomes necessary.

7.2.3 Future risks and opportunities in food systems

This section discusses the future impacts on food systems arising from the risks mentioned in 7.2.2. While quantitative evidence on future impacts is limited, there is more confidence in the expected 'direction of travel'.

Risks associated with production shocks, supply chains and food safety (risks It1 and It2)

Increase in risks due to extreme events

The incidence of extreme events is projected to increase globally (Field et al., 2012), causing an increase in the likelihood of supply chain and production shocks. The year-to-year variability of food production yields is projected to increase, due to extreme events (Challinor et al., 2014a). Existing risks of production shocks and supply chain disturbance are also projected to increase over the century with further warming. For example, the chance of losing 10% of the world's calories in any given year is currently about 1%, but over the period 2011 – 2045 this risk is projected to increase by a factor of two or three (GFS, 2015a).

Longer-term climate change will tend to exacerbate existing food quality and safety risks, via increased extremes, and introduce new risks due to changes in geographical spread.

Food safety

Food safety is likely to be impacted by climate change through the sensitivity of food-borne pathogens and their associated diseases to changes in temperature.

In addition to the public health risks, mycotoxins disrupt international trade. For example, of all the food safety hazards, they triggered the highest number of notifications in the EU in 2006. Risks are projected to increase with climate change. For example, model projections show an increase in risks of occurrence of *Fusarium* head blight in wheat in South America and in the UK. EU limits on toxin concentrations are projected to be exceeded by 2050 (Chakraborty and Newton, 2011). GMO has the potential to reduce mycotoxin incidence (Wu, 2006).

As a result of climate change, livestock could experience outbreaks of severe diseases novel to that population. The lack of previous exposure implies no evolved genetic resistance, and therefore greater risk (Thornton et al., 2009). There is the potential for some livestock diseases to be communicable to humans (e.g. avian flu) suggesting that this issue is potentially broader than an issue of food safety.

Food quality

Climate change will affect the quality of numerous foods. There is evidence that the carbohydrate composition of food crops is systematically altered under elevated carbon dioxide, with various implications, including increased digestive problems (Damatta et al., 2010). The protein content of most crops decreases under elevated carbon dioxide levels, resulting in impaired quality (Taub et al., 2008). A reduction in mineral nutrient and protein concentration of wheat grain negatively impacts bread quality (Blumenthal et al., 1996; Fernando et al., 2012), and reduces the nutritional quality of the final food. Interactions with temperature can further reduce the protein content (Bai et al., 2005) and the subsequent quality of the bread.

Substitution

Substitution is affected by changes in climate suitability, with substitution becoming even more likely for ingredients with limited supply and strong demand. In the example of cocoa, as climatic suitability envelopes alter, some parts of Côte d'Ivoire will be unable to grow cocoa, while others will need new management techniques, and yet others may become more productive (Laderach et al., 2013). If these changes are not well managed then cocoa production may fall, and global prices rise. Substitution of cocoa butter with palm oil derivatives (Undurraga et al., 2001) may therefore become more likely.

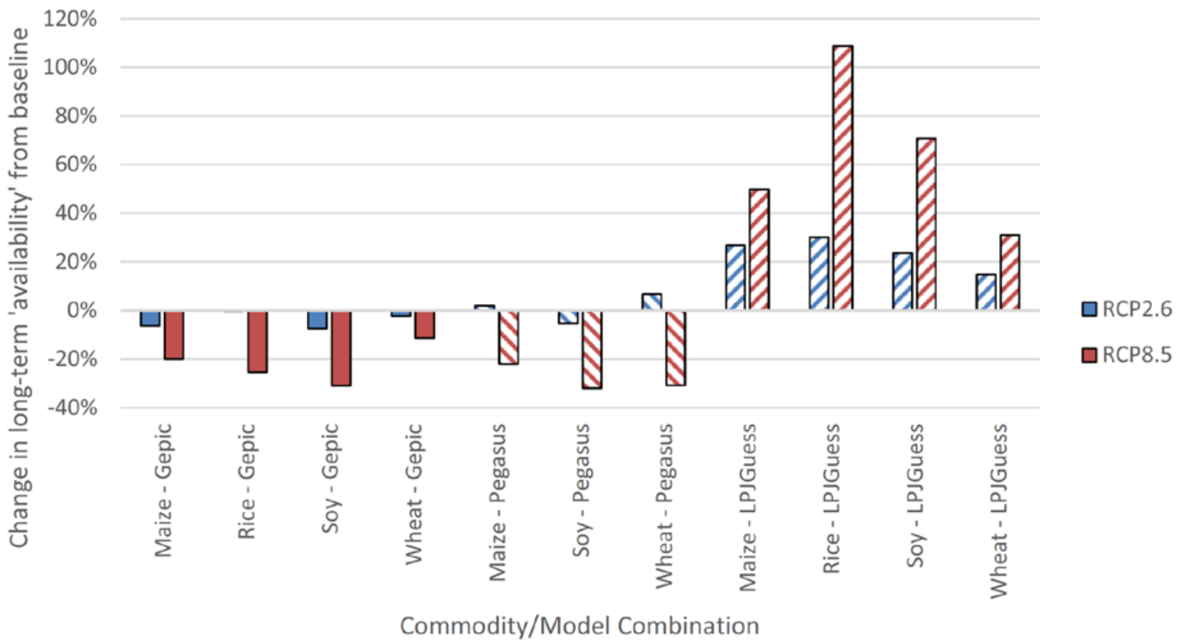
Changes in global food production patterns (It3)

In tandem with population growth, climate change will place increased pressure on the food system over the coming decades (e.g. Poppy et al., 2014). Mean changes in crop suitability, water availability and prevalence of pests and diseases will alter global production patterns (Lane and Jarvis, 2007; Garrett et al., 2013; Elliott et al., 2014). New opportunities will exist, especially in temperate regions. For example, suitability for crop cultivation is likely to increase in the northern hemisphere(e.g. Canada, China and Russia, though this may be constrained by soil quality), while the southern hemisphere more regions with decreasing suitability, mostly in the tropics (Zabel et al., 2014).

However, despite changes in the average conditions, long-term projections cannot be framed as simple linear trends. This is because long-term climate change can contain significant decadal variability (Hawkins et al., 2014). Relative changes in the means and variability of climate (extreme weather and its impacts: risk It1), as well as the compounding effect of non-climate factors, such as deforestation (Lawrence and Vandecar, 2015; It1), make it difficult to project exactly how a change in average conditions will affect agricultural productivity.

- West et al. (2015) assessed the impact of climate change on food commodity chains that are crucial for UK food consumption (Figure 7.5).

Figure 7.5. Projected changes in agricultural production for key staple crops by the end of the century



Source: West et al., 2015.
Notes: Pegasus, GEPIC and LPJ-Guess are three Global Gridded Crop Models (GGCMs) modelling global national-level yields. Pegasus and GEPIC are models without irrigation or CO_2 fertilisation, generally projecting decreasing yields; LPJ-Guess is a GGCM model that includes CO_2 fertilisation effects and full irrigation, generally projecting increasing yields (West et al., 2015, AVOID2 project).

The large variation between the scenarios shown in figure 7.5 is due to the selection of climate scenarios and crop models focussing deliberately on the extremes of model behaviour. There is considerable uncertainty and no consensus on the sign of the change in global production (or its annual variability) in the evidence presented in this report.

In general, there is no single quantification of the risk posed by climate change to key growing regions worldwide. Additional risks due to ground level ozone, including contributions from transboundary NO_x, are currently significant (Hollaway et al., 2012), and will grow if future emissions increase.

The effect of changes in future prices is potentially high, although the contribution of climate change over other factors such as economic growth and demography is unclear. For example, wheat prices could rise by 54% by 2050 due to climate change and other non-climate drivers; but would rise by 23% with perfect mitigation to keep the climate change effect constant (Nelson et. al, 2009. For maize, world prices would increase by 100% by 2050 due to climate and non-climate drivers; but with mitigation, maize prices would rise by 32% (Nelson et. al, 2010). Schmidhuber and Tubiello (2007) suggest that socioeconomic factors will dominate climate change. Similarly Baldos and Hertel (2014) conclude that the impact of climate change is easily dominated by other demand and supply drivers, income growth in the case of wheat and total factor productivity in the case of maize.

The global geography of crop cultivation will also be impacted by changes in water availability (see Box 7.2).

Crop production is not the only food source to be affected by climate and non-climate changes. Globally, at least 4.5 billion people source 15% or more of their intake of animal protein from fish (Bene et al., 2015). Overfishing is currently an issue globally and the potential for fish to contribute to global food security is dependent on sustainable fisheries management and the quantity of fish protein used for animal feeds (Merino et al., 2012). Climate change is impacting global fish stocks, especially in terms of the redistribution of species, which will challenge fisheries productivity in sensitive regions (Porter et al., 2014). Potential fish production could decrease by 30 – 60% in some areas of tropical shelf and upwelling seas, while pelagic predators are projected to increase by 28 – 89% in the higher latitude sea shelf (Blanchard et al., 2012). It is not clear whether this would impact the resilience of the UK food system, given the current modest contribution of fish to the UK diet (Defra, 2012a). The UK population consumes on average 2% of average daily calories from fish against, for example, 10% from meat and about 11% from milk and dairy (Defra, 2011). Trends of fish consumption in the UK are also declining as fish is usually substituted with other food as prices rise (Defra, 2012a). Within the UK, the extent to which ocean acidification may impact marine ecosystems and production potential is uncertain and more research is needed (NE12, Chapter 3).

Autonomous adaptation across the globe has some capacity to moderate the impacts of climate change on crops. Simple agronomic adaptation such as a change in planting date, increase in irrigation or change in crop variety can reduce, or even reverse negative impacts on yield. However, in the longer term, at the latest by 2050, more systemic changes are likely to be required (Vermeulen et al., 2013; Challinor et al., 2014b). Identifying the appropriate longer-term investments will require monitoring of existing trends, and assessment of their likely sustainability.

Tipping points in the climate remain outside the scope of the vast majority of food production assessments, despite their high potential impact (Lenton and Schellnhuber, 2007; Lenton and Ciscar, 2013). Many climate-driven ecosystem regime shifts are related to food production and many share common drivers (Rocha et al., 2015), yet their impacts remain largely unknown or unquantified (King at al., 2015). For example, tropical deforestation can induce a continental-scale tipping point in climate and affect agriculture across the globe, but the magnitude of the risk is unknown (Lawrence and Vandecar, 2015). Similarly, ocean warming and acidification has the potential to tip ecosystems, such as coral reefs, into rapid decline (Hoegh-Guldberg et al., 2007). Further, it is unclear how the gradual changes in climate that affect global production patterns will interact with the growing incidence of extreme events to determine the agricultural landscapes of the future. More research is needed, not just into the underlying processes and likely outcomes, but also into the capacity of global agricultural and fisheries systems to be resilient in the face of climate change. Given the current lack of knowledge regarding abrupt change, monitoring – and where appropriate protecting – production overseas is a key UK policy gap. Such actions would have long lead times, making early detection and action of particular importance.

Despite adaptation, reductions in overseas crop, livestock and fisheries productivity may alter food availability (Porter et al., 2014). Given the globalised nature of markets, the risk of shortages in any one major food is likely to be low relative to any risks posed by market responses (but note the increasing risks of food substitution, and decreased safety and quality – risk It2, above). In particular, shifts in global production patterns may create a domestic business opportunity that could in turn lead to unsustainable practices being adopted. For example, rising wheat prices may result in a reduction of non-cropped land within agricultural landscapes, which may have implications for soils, water and biodiversity (English Nature, 1997). Maintaining natural capital to retain essential ecosystem services is an important area of public policy. There is some evidence of hedge removal in East Anglia, following the wheat price spike of 2012. If there is strong market-driven incentivisation of production, it becomes even more imperative to ensure it is sustainable. Chapter 3 discusses the implications of climate change for UK agriculture in more detail.

The intensification of production will be limited by the amount and quality of agricultural land and the availability and costs of energy, inputs and water, as well as the need to conserve ecosystem services (water and soil quality, biodiversity and the cultural, recreational and amenity value of the countryside). Further limits will be imposed by year-to-year fluctuations in weather: more extremes of precipitation and temperature may cause direct yield losses and logistical problems (e.g. flooding in fields, difficulty in accessing the land, and soil compaction and loss). The manner in which the geography of global productivity changes over time will also depend on the combined impacts of changes in suitability of land to grow crops, and increases in extreme events.

Within Europe, overall yields under a business as usual projection (3.5°C of global warming compared to pre-industrial levels) have been projected to decrease by around 10% by the 2080s. This change is not evenly distributed, however, with southern Europe experiencing 20% decreases (JRC, 2014). A more moderate scenario involving 2°C of warming still causes an 18% decrease in yields in southern Europe, even though this is counterbalanced by an expected increase of 32% in northern Europe, and 101% in the UK and Ireland. Given that EU states are major UK trading partners; this may provide an opportunity for increased exports. However, three issues make this opportunity less than clear-cut:

- There is evidence that soil fertility in England and Wales has declined in recent decades and the number of areas classified as 'poor quality' agricultural land is projected to increase from 14% currently to 70% by 2080 under the high emissions scenario; to 42% in a low emissions scenario and 57% in a medium emissions scenario. The proportion of 'good quality' agricultural land is projected to fall from 38% currently to 4% (11% in a low emissions scenario, 7% in a medium emissions scenario) (Defra, 2014a) (Chapter 3).
- If climate change and extreme weather in the UK are not well managed, then the UK may become less productive and hence more dependent on imports. For example, there is some evidence that winter wheat in northern Europe will experience more adverse weather events than the south (Trnka et al., 2014; Trnka et al., 2015) (Chapter 3).
- Water availability for irrigation will also be a limiting factor for UK food production.
- The agricultural sector in the UK is reliant on migrant labour, with a strong presence of EU migrants in UK food and agriculture sectors. Within Europe there is a higher likelihood of negative impacts of climate change on agricultural production and on demand for labour. This will have impacts, for example, on migration patterns in Mediterranean countries. However, this is expected to lead predominantly to short distance rural–urban migration within countries (Ciscar et al., 2011; de Haas, 2011; Foresight Report, 2011b).

Looking forward, there is a need to identify the limits of sustainable production in the UK, both to protect domestic agriculture and also to act as a leader in global political thinking on sustainable production.

Opportunity from changes in international trade routes (It7)

The opening up of Arctic trade routes presents an opportunity for increased trade. Using Arctic trade routes to Asia will not likely affect trade volumes, but may help reduce transportation costs. It may also make the Pacific coast ports more accessible (via the Bering Strait), enabling more trade from the US extra-East Coast/Mississippi routes. The types of cargo carried over long distances between continents and the extra costs of these routes suggest that opportunities will remain limited out to 2050 and beyond (see Box 7.3).

Currently Arctic shipping is a niche market undertaken by a small number of specialist shipping providers (primarily Fednav in the North West Passage and Sovcomflot in the Northern Sea route). The UK could be involved in insurance and other maritime services for these regions (Box 7.3).

Box 7.3. Opportunities for the UK from Arctic change

Assessments suggest that the potential for increased shipping activity in the Arctic will remain limited to 2050 and beyond. The potential for growth is most closely identified with increased demand for local community re-supply operations and tourism. It is anticipated that increased fishing and resource development may also increase demand for so-called destinational shipping (journeys between specific ports other than the major hub ports), but the extent of these activities in the future is uncertain.

Shipping industry sources suggest the UK may benefit from increased access to the Arctic as a consequence of climate change. The main area where the UK could benefit is from increased tourism such as an increase in the number of UK registered cruise ships, if UK ports are increasingly used as a point of embarkation for passengers visiting the Arctic, and if UK domiciled tour and expedition operators are able to increase their market share.

The UK could benefit from the provision of maritime services, especially from companies based in the City of London. UK companies are well placed to provide finance, insurance, underwriting, certification and classification, all of which will be necessary enablers of maritime activity in the Artic. However, insurers and underwriters remain cautious about providing services to Arctic shipping due to the potential risks involved.

Sources: Lloyds (2014); Marsh (2014).

7.2.4 Current adaptation and policy gaps

As discussed in Section 7.2.1, UK objectives on food security focus on minimising market distortion and sustainable intensification supported by agri-tech innovation (Chapter 3 and Section 7.2.1).

The first of the Government's food security objectives aims to ensure a well-functioning trade system, tracked through the UK Food Security Assessment, which consists of monitoring a series of indicators (Defra, 2010). However, there are gaps in this approach. Under 'normal' conditions, and with a well-functioning and transparent market, a disturbance in one place will be buffered by the diversity of locations involved in trade. A strong reliance on international markets is sensible under ‘normal’ conditions. It promotes competitiveness on a global basis, reducing prices for consumers and creating economic gains for the best producers. The best producers are those that maximise efficiency (typically at scale) and make the most of local resources, including natural assets.

However, climate change is changing weather patterns and ‘normal’ conditions are increasingly abnormal. Furthermore, two structural issues are creating systemic global risks (Centeno, 2015). First, international trade in commodities is increasing. Every country increasingly relies on trade to supply basic needs, which is a positive attribute when the market is stable but contributes to vulnerability if the market is disrupted (Puma et al., 2015). Second, the network structure is asymmetrical. Some breadbasket countries supply large amounts and thus are highly important nodes in the global market, connected to many countries around the world (Puma et al., 2015). Both these factors imply risks to the resilience of the global food system (GFS, 2015a; Lloyds, 2015; Puma et al., 2015). Individual countries are embedded in a global system and unprecedented events coupled with over-compensatory market responses (mediated via export taxes, financialisation of commodity markets, biofuels, low levels of stocks, oil prices and exchange rates) can amplify shocks that propagate globally. As the system is global, no single country can manage it. Instead, there is a need to cooperate internationally to try to manage the market and achieve a resilient system.

Climate change and extreme weather will reduce the resilience of highly efficient but vulnerable systems, that are well-adapted to normal conditions but without the ability to cope under stress. It is important that policy and international co-operation focus on stress testing the resilience of global markets to extreme and unprecedented conditions. Otherwise, the market will naturally respond to production with price spikes, with the implications for global markets and behaviour by individual trading partners as already discussed.

The second and third elements of the Government’s food security strategy both aim to increase domestic production. Defra’s Sustainable Intensification Platform involves a number of pilot projects investigating ways to increase farm productivity while reducing environmental impacts and enhancing ecosystem services (Defra, 2013). The Government’s agri-tech strategy (HM Government, 2013) likewise aims to invest in intensifying production in a sustainable way. The CAP also aims to support the sustainable intensification of agriculture. However, sustainable intensification of UK production does not ensure UK food security. This is because (i) UK food security fundamentally relies on access to international markets and is not simply a property of growing more of what we are good at farming and (ii) sustainable intensification of agriculture does not necessarily create a resilient supply of food. It has not been possible to assess the effectiveness of the agri-tech strategy in helping to achieve the Government’s food security objectives, as evidence of the strategy’s impact is not yet available. There are also risks associated with the use of resources, in particular given the current state of soils (see Section 7.2.3 and Chapter 3)

In general, the Government’s current food security objectives do not address the food insecurity faced by the poorest economically in the UK or the resilience of the global food system. Sustainable intensification and increasing domestic agricultural production do not in themselves ensure access to affordable, safe food.

The above analysis applies to the UK has a whole, since, while food security is a devolved matter, the goals of the devolved governments are similar to Defra’s policy objectives. National policies across the UK are mainly focused on domestic production, though different national governments take slightly differing roles in how they achieve it. For example, in Northern Ireland the Government sets strategic regional land management policies to determine the most productive use of land.

Climate resilience and food system sustainability are not currently core elements of food security policy. Given the global interconnected nature of food systems, resilience can only be built systemically. This, in turn, implies that policies be at least partially co-ordinated across different government departments and across international borders. Systemic resilience of the UK to the impact of extreme events abroad is of particular importance in ensuring long-term food security and capitalising on the opportunities associated with climate change. In the longer term the uncertainty in overall productivity, which results from the combined effects of extreme events and shifts in suitability (Section 7.4.2), creates an additional need for flexible and strategic policy on long-term resilience and sustainability.

In summary, the main overall gap in relation to food is the **lack of strategic co-ordination to build systemic resilience of the food system**. There is currently no overarching strategy to tackle systemic vulnerability in the food system and to assess and measure the effectiveness of single actions (e.g. those promoting sustainability of agriculture or reducing waste) in tackling systemic vulnerabilities. The assumption that the market will deal with these issues is implicit, yet market responses to unprecedented or rare events may be unpredictable and exacerbate problems rather than solve them. Market actors therefore need strategic support to assess, analyse and adapt to growing systemic threats. In the area of food safety, for example, monitoring of trends and emerging threats beyond UK borders is central to identifying specific future risks.

The House of Commons EFRA committee on food security has recommended that Defra appoint a Food Security Coordinator in order to bring about greater coherence across government on food security (EFRA, 2014). The need for a policy framework on food has been identified by stakeholders as a requirement, with its urgency resulting from the long lead times involved (PricewaterhouseCoopers, 2013, p. 47). The majority of risks identified here are considered to be not addressed due to the lack of a unified system or process to understand and manage UK food security in a global context; and the opportunities cannot be capitalised upon without joined-up thinking across government and beyond. The resilience of the food system is a cross-departmental and cross-disciplinary issue; a Food Security Coordinator, if appointed, would therefore need to be cross-departmental (or independent) and multidisciplinary. This could be, for example, a strategic committee tasked with assessing evidence and improving management of knowledge and data in order to tackle systemic vulnerability of the food system. Over the last 5 years, the UK's Global Food Security programme has provided some degree of cross-governmental analysis and horizon scanning capability. However, with the development of new research funding mechanisms, the UK's Global Food Security programme is likely to cease.

Incomplete understanding of the interconnections between components of the global food system, including between public and private bodies, is a major barrier to determining appropriate policy options. For example, a policy that forces supermarkets to donate excess food to charity (such as the policy introduced by France in 2015) improves food security and reduces waste in the short term, but it may discourage development of longer-term changes that could improve efficiency in the long term. Collective agreement between nations will then be important in ensuring market function and broader resilience in response to food shocks. The CAP, for example, could be an opportunity to build resilience, rather than being viewed as a simply a market distortion. Alongside international agreements, there are important roles for UK policy: supporting diversity of UK production as buffer to international shocks; and exploiting the significant opportunities presented by climate change to catalyse improved food security, with the co-benefit of increased systemic resilience. Where international boundaries are crossed, as is the case with the global food system, separating exogenous and endogenous factors is extremely difficult (see e.g. (PricewaterhouseCoopers, 2013). The use of plausible scenarios of multiple inter-related events provides a useful parallel of evidence for governments, international institutions and businesses to explore opportunities for co-ordinated risk management (GFS, 2015a). However, systemic failure might not be captured by this scenario-based assessment. A systemic approach should acknowledge that the system is non-static, thus the solutions have to be adaptable, rather than rigidly applicable to a particular snapshot of the system (Downing, 2012).

Areas in which strategic co-ordination is needed include (Table 7.3):

- **Management of change in the UK farm sector to improve systemic resilience.** Current policy to support open access to markets does provide some resilience. Further policies to improve the functioning of international trade and markets would be beneficial. Market indicators, such as stock-to-use and productivity, cannot be relied upon to ensure resilience, since they lack any information on transience, which is central to any risk assessment. There is an important branch of economic and evolutionary theory concerning the relative performance of a system in stable versus variable conditions. If variability is sufficient, increasing the resilience of the system (by reducing the fluctuations in performance) may be a more favourable outcome, even if this has a cost in the long run. If the likelihood of extreme weather is increasing, building resilience of our agricultural sector, even if it comes at the expense of a reduction in average productivity, may be a rational strategy. As an example, in a stable world, UK production of a specific food might struggle to be competitive on a global basis. However, in the event of market disturbances, local production may have strategic importance. But this should not be taken as a call to achieve domestic self-sufficiency, which would be inefficient as well as unachievable in practice (Benton, 2013). The global interconnected nature of food chains, coupled with the risk of climate-induced production shocks and market responses (i.e. risk It1) leads to an increased tendency for fluctuating market conditions. Under disruption, some strategically important sectors or businesses may become (periodically) unviable economically. A UK food strategy needs to assess the strategic importance of building resilience and maintaining (or increasing) a diversity of production systems versus the economic costs (in the short and long term, under ‘normal’ and ’crisis’ conditions). Resilience to longer-term changes in agricultural productivity – and any corresponding increased reliance on imports, or tendency towards unsustainable intensification (risk It3) – will depend on how government policies and market signals influence the UK farm sector.
- **Support business, innovation and aid aimed at opportunities and adaptation overseas.** Climate change presents challenges on both short (e.g. risk It1) and long timescales. Major long-term agricultural transformations will be required across the globe (risk It3). Some of these changes will occur through market mechanisms and business investment, while others will require policy support. There is also the potential for some business-led systemic changes to be counterproductive in the long run (Rippke et al., 2016) simply by virtue of their focus on shorter-term profits. Policy, supported by science, needs to identify the appropriate pace of change for global agricultural systems, and support it. For example, the relative merits of maintaining current cropped areas through increased investment in irrigation versus infrastructure for systemic changes in crop production need to be assessed (Elliott et al., 2014). The UK can play a leading role in supporting overseas agricultural adaptation. This

represents not just a business opportunity, but also a lever for increasing resilience of the global food system. UK business and foreign aid can act to increase resilience in both the short and long term, for example, by helping maintain overseas transport and logistics, increasing adaptive capacity, promoting sustainability and increasing productivity (See Opportunity It1). This, in turn, will reduce UK vulnerability to climate change. A well-managed UK farm sector and improved management of knowledge and data (see above) underpin much of this potential.

- **Resilience of supply chains.** Supply chains can be affected by extreme weather directly via transport, and indirectly via price spikes. Weather forecasting, from lead times of hours up to a season, has the potential to strongly underpin resilience by supporting targeted action. Capacity in global forecasting of risks from extreme events should therefore be supported, especially where it is possible to provide high resolution information relating to key transport nodes or production regions. The GFS report (GFS, 2015a) noted that there is considerable uncertainty about increasing food system risks due to extreme weather and climate change. Significant new research is needed to characterise it (e.g. AVOID2, 2014). There is also an urgent need to develop understanding and capability leading to risk assessment for multiple simultaneous breadbasket failures resulting from coincident weather shocks in key regions. Any action that builds supply chain resilience directly addresses (risk It1), as well as supporting exports. Actions to build resilience in supply chains can be anticipatory or reactionary, in isolation or in combination.
- **Identification of emerging food fraud and contamination risks.** This action is a direct result of risk It2. Required interventions will likely build upon existing food safety quality regulation, as well as coordination between the main departments responsible (FSA, FSS and Defra). Areas at high risk of fraud and contamination need to be identified and targeted in order to close loopholes and provide consumer assurance. Increased surveillance and prediction, co-ordinated mechanisms for obtaining rapid expert advice, and maintenance of strategic food stocks are some potential intervention points (Tirado et al., 2010). Changes in climate and geopolitics, coupled with the complex and international nature of supply chains, mean that going forward, monitoring food safety at point of entry will remain necessary, but is unlikely to be an effective strategy on its own. In addition to straightforward monitoring, surveillance techniques can identify opportunities for food fraud and contamination. For example, horse meat substitution was identified following the analysis of the Food Safety Authority in Ireland of the price of beef alongside that of beef products. They noticed that the price of beef was increasing, but not the price of beef products. Policies should be accompanied by institutional coordination as well as capacity building to develop these kinds of surveillance techniques. This would build on the ongoing work of the National Food Crime Unit, based in and led by the FSA.
- **Demand-side management to reduce greenhouse gas emissions from agriculture and support long-term food security.** UK food consumption patterns are among the causes of climate change, as well as the broader environmental impacts arising from the global food system. For example, 50 – 60% of the embedded water resources used to sustain UK consumption of agricultural goods are sourced overseas (GFS, 2015b). Awareness of this footprint is not widespread. Long-term planning in the overseas supply chain is one way for the UK to contribute towards long-term sustainability and equity within the global food system. Any action that increases sustainable practices, for example, by reducing waste or increasing the efficiency of food production, processing and use via reduced consumption

of meat, will support long-term food security at the same time as reducing greenhouse gas emissions. There is also the potential to improve health and nutrition (Chapter 5).

Table 7.3. Policy areas needing strategic coordination to improve resilience of the food system

Description	Policy arena (Dom/EU/Int) and timescale	Actors involved	Address risks	Address opportuniti es
Functioning of international trade and markets	EU, international Immediate	Defra, BIS, Academia, Industry	**It1**	
Management of change in the UK farm sector for systemic resilience to climate change	Domestic, EU All timescales, especially short-to-medium	Defra, Academia, Industry	**It1, It3, Chapter 6, Chapter 3**	**Chapter 6, Chapter 3, It3**
UK business, innovation and aid aimed at opportunities and adaptation overseas	Domestic, international All timescales	BIS, DFID, industry	**It1, It3, Chapter 6**	**Chapter 6, It7, It3**
Resilience into supply chains	EU, international, domestic Immediate	Academia, Defra, FCO, BIS, DoH/ Department for Work and Pensions (DWP)	**It1, Chapter 4, Chapter 6**	**Chapter 6, It3, It7**
Emerging food fraud and contamination risks	Domestic, EU, international Begin planning within 5 years	FSA and SFSA (Fraud and contamination) International monitoring?	**It2, Chapter5**	
Demand-side management	Domestic, EU Immediate action will enable medium-term change	DoE, DoH, BIS, Defra, Department for Communities and Local Government, NHS, consumer associations Big society?	**It3, It1, Chapter 3**	**Chapter 3, It3**

Source: CCRA authors.

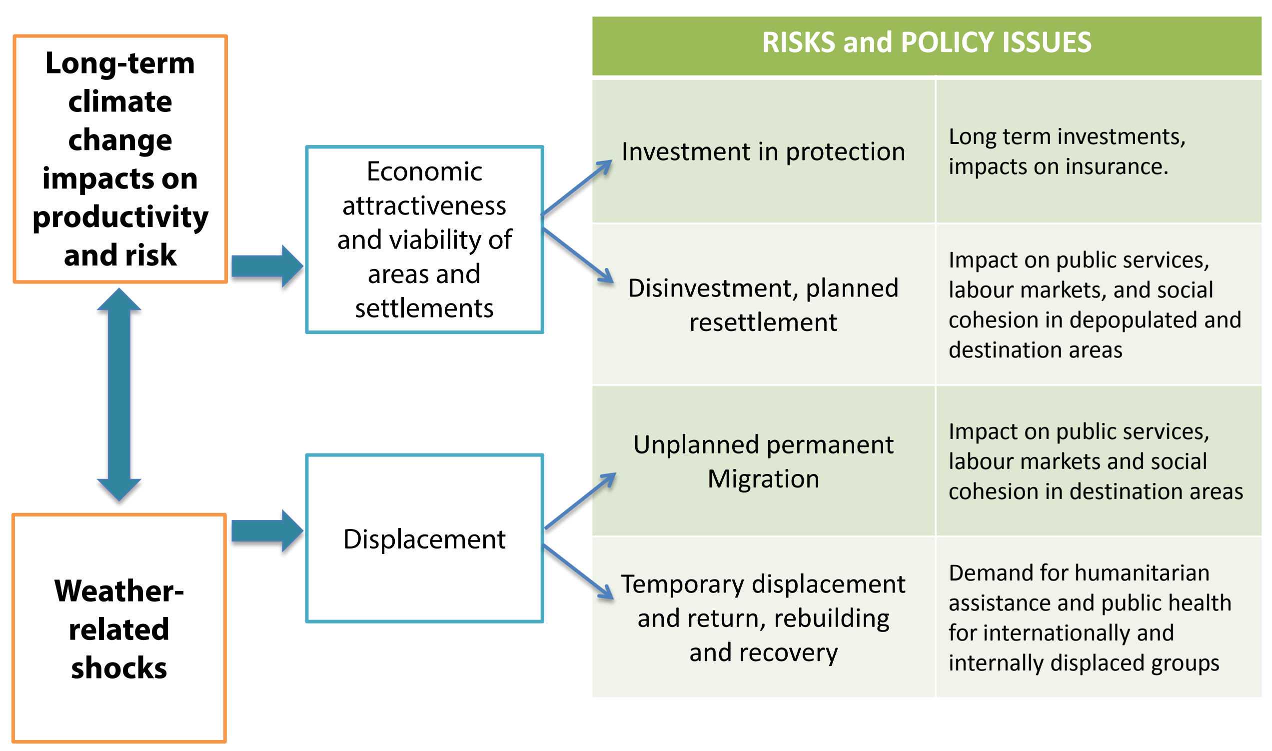
7.3 Dimension 2: Migration and displacement risks

7.3.1 Climate change as a driver of migration

Climate change is unlikely to be the sole direct cause of migration but it will interact with and change the effects of other potential drivers. Drivers of migration include changes in relative wealth and income inequalities, persecution of individuals and communities, and conflict either within or between states. Migration can be short term ('displacement'), and is often within states or to neighbouring countries ('next safe place'). Longer-term international migration arises from sustained internal or regional conflict as well as changes in the economic attractiveness of an area.

Migration has an impact on services, labour markets and long-term investments in both the origin and destination areas (Figure 7.6). The costs and benefits of migration are, in the main, directly incurred by those directly involved. Most voluntary migration brings long-term benefits for both sending and receiving areas. But there are significant social costs associated with both unplanned migration and exposure of people to weather hazards. The key social costs are due to (i) the local social and economic disruption caused by unplanned migration and (ii) the need to support displaced communities with humanitarian aid, or (iii) the investment in climate change adaptation that may be required to avoid exposed populations needing to move and be resettled. There will also be wider political and economic implications arising from migration, and as such it is linked with other geopolitical risks (Figure 7.7). Greater EU and international co-operation on displaced people and unplanned migration will be required.

Figure 7.6. Risks associated with long-term migration and short-term displacement

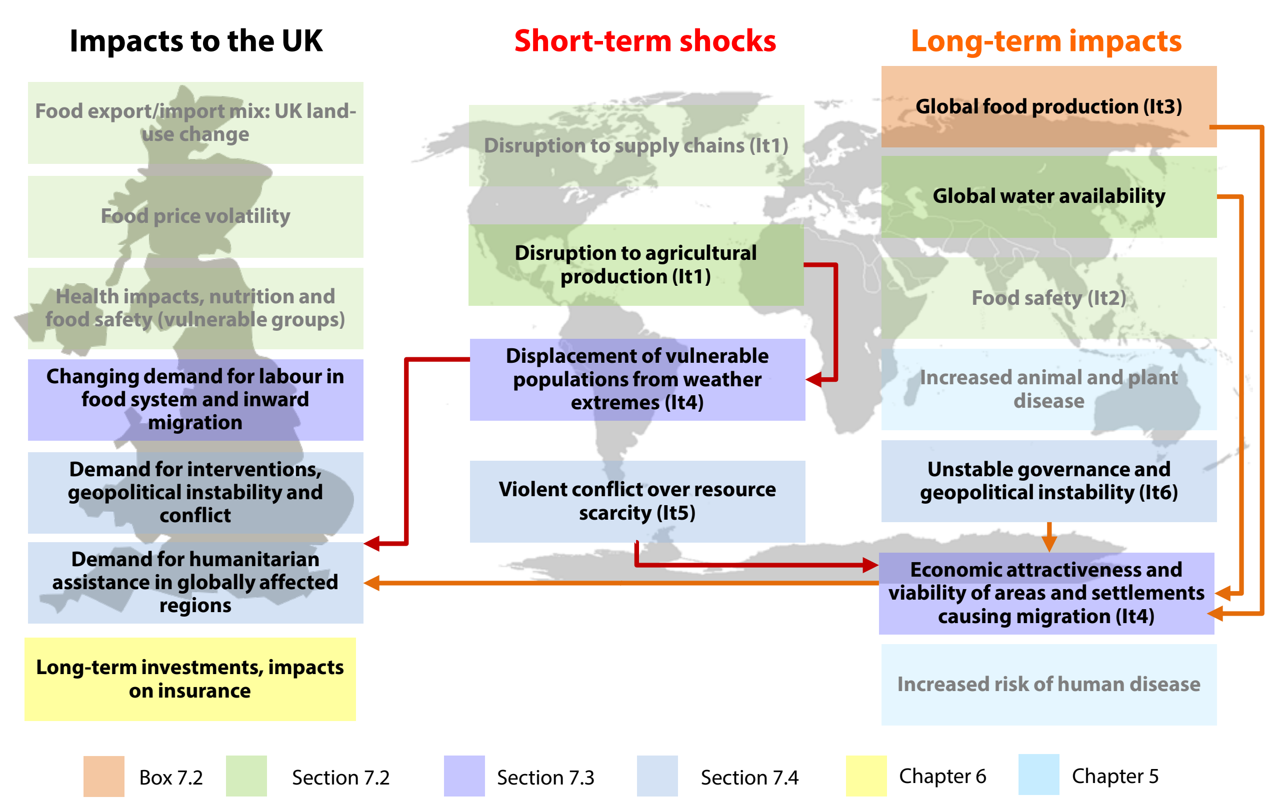


Source: CCRA authors.

Some people may lack the resources to move, and these resources, for example land productivity and incomes, can be affected by climate change. This creates an attendant risk of 'trapped' populations in areas exposed to significant climate-related risks (Black et al., 2011; Foresight Report, 2011b; Raleigh, 2011). Climate change could also alter patterns of migration in complex ways, by changing the relative attractiveness of destination countries.

As displacement following weather extremes is usually limited to the affected areas and adjacent countries, the UK will be less susceptible to inward migration flows arising from displacement from countries outside of the EU. However, this is strongly dependent on UK and EU migration policies that regulate migration flows.

Figure 7.7. Climate drivers, global migration-related risks and impacts on the UK



Source: CCRA authors.

7.3.2 Migration policy

Migration to the UK is managed by UK policies that are currently integrated with EU policies governing inward non-EU migration and free movement of EU citizens. These legal and policy frameworks do not explicitly recognise climate change, not least because of the difficulty of disentangling climate change from the principal drivers of migration.

The UK opt-out from Title IV of the EU Treaty covering free movement, migration and asylum means that the numbers of migrants and displaced people to be admitted to the UK remains a matter for the UK Government to determine. The numbers of non-EU migrants to be admitted is under the competence of the UK policy for admission of non-EU labour migrants, which emphasises admission by higher skilled workers through Tiers 1 and 2 of the work visa programme. The UK Government participated in the first phase of development of the EU's Common European Asylum System (CEAS) and the development of common minimum standards, but in 2011, the Government stated its intention not to participate in further development of the CEAS.

The EU developed the Global Approach to Migration during the 2005 UK Presidency of the EU Council, since renamed the Global Approach to Migration and Mobility (GAMM). This structures EU policy on migration and relations within non-EU member states. EU agencies support operational co-operation on border security (FRONTEX) and asylum (European Asylum Support Office). The UK has observer status within FRONTEX, and has participated in FRONTEX operations. The UK participates in the European Asylum Support Office (EASO), which offers operational support on asylum issues.

In the context of the GAMM and EU climate policy, a Commission Staff Working Document 'Climate change, environmental degradation and migration' (European Commission, 2013a) accompanied the EU Strategy on Adaptation to Climate Change (European Commission, 2013b) to provide an overview of research and data.

International aid policies have an important role to manage this risk as they determine the UK's role in addressing the root causes migration crises.[12] The second pillar of the UK Aid strategy is strengthening resilience and avoiding crises around the world.

7.3.3 Current risks and opportunities relating to migration and displacement

Displacement as a result of weather-related extremes has, in general, much higher risks and costs than more long-term movement of investment and settlements as a result of changing economic comparative advantage.

On the cost side, displacements might result in, for example, increased costs for public services and housing for changing populations in receiving areas. Under these conditions unplanned migration can cause social tension. Out-migration and de-population also have implications on economies of sending areas. Most attention in the relationship between climate change and migration is focused, however, on various forms of regular and irregular unplanned international migration. This represents only a small proportion of the aggregate movement of populations globally when compared to internal migration within states or regular migration flows authorised by national laws. The costs and risks associated with migration, and the relationship to climate change and extreme weather events are shown in Figure 7.7.

Given the projected impacts of climate change globally, there will be an inevitable effect on movement of populations because of the changing economic geography of economic activity and settlement. Migration is a well-established adaptation to such changes, but also includes involuntary migration, or displacement, as a result of extreme weather events.

The assessment here examines how risks from migration are transmitted to the UK. This includes, but is not restricted to, inward international migration of people to the UK. There are other significant transmission mechanisms related to, for example, demand for humanitarian

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[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/478834/ODA_strategy_final_web_0905.pdf

assistance, and political and economic changes in other regions. All of these depend on the effectiveness of coordinated responses across policy domains, particularly at international level.

Risks to the UK from weather-related international human displacements (It4)

Displacement, in this context, means involuntary movement of people from their place of residence due to incidences of floods, coastal inundation, landslides, droughts and wildfires. Displacement is most often temporary and local in nature. For example the Pakistan floods of 2010, led to an estimated 1.6 million damaged or destroyed homes, but virtually all displacement was localised and temporary (Looney, 2012). However, such displacement from extreme events in the past has had significant human cost, including health and economic costs, and also more permanent unplanned migration trends (Adger et al., 2014). Examples of such displacement and long-term migration include the impacts of Hurricane Katrina in the southern US. Significant numbers of those displaced by the storm event migrated permanently to other cities in the US (Fussell et al., 2010).

The Norwegian Research Council provides estimates of displacement as a result of weather-related disasters globally, and estimates 22 million people were displaced in 2013, including over 4 million people affected by Typhoon Haiyan in the Philippines[13]. On average, 27 million people per year were displaced between 2008 and 2013 (IDMC, 2014).

Direct examination of such evidence, undertaken by the Foresight inquiry on Migration and Environmental Change (Foresight Report, 2011b), concluded that the risks of large-scale migration to the UK are low (Fielding, 2011; Findlay, 2011; Foresight Report, 2011b; Harper, 2012). However, there are significant transnational diasporic communities in the UK that are likely to have links to areas affected by changes in climate around the world. Associated flows, such as remittances, have been shown to play a positive role in fostering economic development in disaster-affected areas and sustaining resilience. Officially recorded remittances from the UK in 2011 are estimated at £3.2 billion. World Bank estimates suggest the figure may be considerably higher, with the main recipient countries being India, Nigeria and Poland (World Bank, 2011).

7.3.4 Future risks and opportunities relating to migration

The key future risks are (i) changes in migration flows associated with increased displacement risks from extreme weather events and (ii) changes in migration patterns associated with longer-term impacts of climate change on economic activity. Both have the potential to impact the UK from weather-related international human displacements (It4).

At the global scale, it is well established that slower onset environmental change will interact with other migration drivers to influence primarily internal migration, but also international flows (Black et al., 2011). The effects on migration within the UK as a result of climate change, and changes in international flows (immigration and emigration to/from the UK) because of involuntary displacement are limited. Sensitivity of inward UK migration flows to climatic changes is low for the reasons already discussed; the local and temporary nature of most displacement, and the existence of UK and EU migration policies that regulate migration from affected areas.

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[13] http://www.internal-displacement.org/assets/publications/2014/201409-global-estimates2.pdf

Most projections of socio-economic futures show that migration flows ultimately affect and can make major differences to national populations, and to some extent to the size of regional populations (Foresight Report, 2011b; Samir and Lutz, 2015). At the same time, most projections of future migration demonstrate the importance and necessity of international inward migration for countries with ageing populations and higher dependency ratios (O'Neill et al., 2015). But risks also arise from rapid urbanisation and the growth of urban slum areas in countries in demographic transition.

Risks to the UK from weather-related displacement and migration (It4)

Estimates of displacement associated with changes in all potential climate impacts in future are not reliable, and are reported in a piecemeal fashion, for example, in IPCC reports. However, estimates of populations at risk, and hence potentially displaced due to, for example, living in flood risk zones along coasts, show estimates of more than 70 million potentially at risk of displacement with a 0.5m sea level rise (e.g. Nicholls et al., 2011). All climate scenarios, simulations and overall assessments including the IPCC Special Report on Extremes (Field et al., 2012) point to increasing weather-related displacement in many parts of the world. There are multiple potential causes of displacement; flooding in low-lying areas; flooding and storm surges in coastal areas; and drought in countries without major social safety nets for farming populations.

A key risk is vulnerable groups who lack the resources to move and can be 'trapped' in areas exposed to high climate risk. This will limit international migration flows to the UK due to the high cost to migrants of such long distance movements. Hence, climate change may not be strongly detectable as cause for UK international migration arrivals. Rather, the impacts of climate change, especially on resource-dependent sectors in developing countries, may increase the likelihood of shorter distance movements within countries and to neighbouring states (Foresight Report, 2011b; Hugo, 1996).

Future scenarios where population movements are constrained such as Shared Socio-Economic Pathways SSP3 'Regional Rivalry' (O'Neill et al., 2015), highlight how population movements can lead to poorly planned settlements around large urban areas. This is to be expected particularly in low-income countries with greater populations at risk from the impacts of weather-related extremes.

One further and major issue is the displacement associated with civil conflict and how such conflict could be affected by climate change. There is an ongoing, contested scientific debate on the causality between climate change, resource scarcity and the triggering or amplification of civil conflict and risk. While some studies portray the links as self-evident, other analysis has found no compelling evidence, as yet, that climate change has been a significant factor in the pattern of observed conflicts over the past half century (Gledditsch, 2012). There is, for example, contested evidence on the role of drought in the present Syrian conflict (Gleick, 2014). Kelley et al. (2015) highlight that Syria experienced drought since 2006, and that the likelihood of this drought was exacerbated by climate change. However, there is no academically agreed evidence that the drought conditions in the region, including in neighbouring countries, were a significant cause or trigger of the present conflict in Syria. In summary, the complex dynamics of conflict in Syria and the region involve multiple factors, even if drought conditions contributed to the complex emergency.

The IPCC reports conclude that the role of climate change in conflict is uncertain, but there are significant reasons for concern in the future if climate change were to affect the livelihood of poor populations, given the strong association of poverty with civil conflict (Adger et al., 2014).

Altered settlement and migration patterns due to changing economic viability (It4)

As well as immediate displacement and migration risks, discussed above, climate change will interact with longer-term economic trends to potentially affect migration flows. Some potential mechanisms are (i) disinvestment in areas at risk, including withdrawal of insurance, making them less economically attractive; and (ii) planned relocation of settlements.

Slower onset and longer-term environmental changes interact with well-established economic, social, political and demographic drivers of migration, and with wider global trends, such as urbanisation, to make some areas less attractive as destinations. Slower onset climatic changes include rising sea levels and coastal inundation, changes in tropical storm and cyclone frequency or intensity, changes in rainfall regimes, increases in temperature and melting of mountain glaciers.

Coastal areas might be particularly impacted as property and agricultural land in coastal areas may be considered too expensive to protect against increasing coastal storminess and sea-level rise. The increasing costs of coastal protection are evidenced around the world, with projections often assuming that protection that is affordable to a country will be implemented (Hinkel et al., 2014). Hallegatte (2012) demonstrates that economic activities to defend urban infrastructure from sea-level rise risk locking-in patterns of development that ultimately have high costs and may not be sustainable in the long run.

Long-term shifts in economic prosperity affect overall migration flows towards economic opportunities in less affected regions. Some sectors, such as agriculture may change their demand for non-UK labour, but assessments to date portray impacts as marginal with many mediating factors (Findlay, 2011; Foresight Report, 2011b).

All changes in inward migration patterns to the UK, whether associated with climate change or economic drivers, might lead to increased demand for a range of social services. Both migration and routine travel contribute to spread disease, and thus attribution to migration is unclear (PricewaterhouseCoopers, 2013). Fielding (2011) stresses the importance of effective governance of health care and assesses the risk of disease transmission as low (see discussion below). As highlighted above, the UK agricultural sector also represents a demand for international seasonal labour and hence the resilience of the UK agricultural sector depends on the availability of labour at peak harvest and other seasons (see, for example, Migration Advisory Committee, 2013; Scott et al., 2008). Migrant workers also play an important role in the provision of health and social care in the UK.

7.3.5 Current adaptation and policy gaps

Many policy areas interact to result in net migration flows. Trends in demographic change, ageing populations, labour market integration and other issues affect every region of the world (Harper, 2012).

Multilateral action will likely be required to address migration issues. For the UK, national restrictions alone are unlikely to reduce the flows of international migrants linked to income and wealth inequalities, the effects of conflict either within or between states, and the risks associated with people smuggling and trafficking.

The assessment and management of risks from changes in migration patterns associated with climate change are therefore dependent on the effectiveness of international responses to migration, particularly at EU level given its geographical position and pressures.[14] There are also already links between UK and EU migration and other policy fields such as adaptation to climate change within Europe, poverty reduction, development assistance in sending countries, and peace and security interventions overseas.

The European Agenda on Migration (European Commission, 2015) identified climate change as a potential cause of displacement along with civil war, persecution and poverty. Proposed measures included military action to combat smuggling networks, as well as efforts to address root causes of migration and consider legal options for migration to the EU. The UK has not opted in to any of the EU's immigration directives covering long-term residents who are third country nationals, family reunification, return of illegal immigrants, and migrant workers in seasonal employment. The UK has consistently asserted its right to maintain border controls and does not participate in the EU's Schengen system.

For example, the UK Government has declined to participate in a Commission-proposed plan for the EU/ United Nations High Commissioner for Refugees (UNHCR) to relocate 20,000 vulnerable people from the Middle East, North Africa and the Horn of Africa to EU member states and in Commission plans to relocate up to 40,000 asylum applicants from Italy and Greece. The EU relocation scheme target was expanded on 22 Sept 2015 to provide for an additional 120,000 asylum applicants (http://europa.eu/rapid/press-release_STATEMENT-15-5697_en.htm).

The UK Government participates in the Steering Group of the Khartoum Process of dialogue on migration between the EU and African Union. This is focused on the Horn of Africa, but without explicit reference in its remit to effects of climate change on migration.

To develop links with other policy areas that enhance climate resilience outside the UK, policy gaps include:

- Enhancing regulations and interventions to avoid the existing gap in policies and formal mechanisms that leave migrants in need for legal recognition, primary assistance, safe relocation or return (the so-called 'protection gap').
- Planning for integrated resilience in countries worldwide by improving both the urban and rural environments and building sustainable communities able to cope with climate change and extreme weather impacts.
- Facilitating migration as a form of adaptation to climate change through, for example, schemes promoting temporary or circular migration.
- Developing a co-ordinated response at EU level through assessing the role of migration and displacement within EU strategies for agriculture and development.
- Ensuring secure and effective mechanisms for the transmission of remittances.

There have been significant calls for greater recognition in political systems of populations displaced, or potentially displaced in the future because of climate change. This could include giving people permanently displaced from their homes recognition under the Geneva

[14] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/478834/ODA_strategy_final_web_0905.pdf

Convention on Refugees (Biermann and Boas, 2008). However, changes to international protection laws to cover 'environmental' or 'climate' refugees have been largely ruled out, or are highly unlikely because of (i) the impossibility of disentangling environmental causes of displacement from other economic, social, political and demographic drivers and (ii) the existence of little evidence of political or legal support at national or international level, including from UNHCR, for such measures (Foresight Report, 2011b; McAdam, 2011; Piguet et al., 2011). Substantive progress is more likely through state-led consultative processes such as the state-led Nansen Initiative or through recognition in existing mechanisms such as the Kampala Convention covering internal displacement in the African Union.

On the other hand, international development aid plays a crucial role in managing the underlying causes of migration (Ashdown, 2011), which gaps are discussed in 7.4.4. Addressing these gaps will play a crucial role to manage migration risk, and unilateral intervention has limited scope, hence the importance of the UK's role in ifluencing and fostering international goals on development.

As mentioned above, much of the scientific literature concludes that it is impractical to disentangle climate change from other drivers of migration (Adger et al., 2014). Climate change is therefore not a simple 'migration trigger'. Interactions of climate change with income and wealth inequalities, and with conflict within or between states, can lead people to move, but the majority of this movement is likely to be within states or to neighbouring states. The effects of income and wealth inequalities and of conflict may also be to make it more difficult for some people to move, with the risk that they become 'trapped' in areas in which they are exposed to climate risk.

There are benefits for policy initiatives that build sensitivity to climate change into wider migration policies. For example, UK engagement with the EU and wider international policy framework on migration could ensure it incorporates and anticipates climate change impacts on existing migration flows. Policy appraisal could consider both the likely migration flows and the effects of immobility among vulnerable populations. The range of policy areas affected is broad, including development, adaptation, urban resilience, and peace and security. International co-ordination of these policy fields need to be integrated into migration policy (European Commission, 2013a). The need for incorporation of displacement and complex emergencies in defence planning is recognised in assessing strategic trends, such as the Global Strategic Trends to 2045 developed by the Ministry of Defence.

7.4 Dimension 3: Risks associated with geopolitical dimensions of climate change

7.4.1 Climate change and geopolitical risks

Climate change poses significant risks to national and international security through economic costs and risks to territorial integrity. The impacts of climate change are highlighted in many scientific assessments as threat multipliers in already fragile states and regions, acting by increasing the stress on governance structures and resource availability (Figure 7.8).

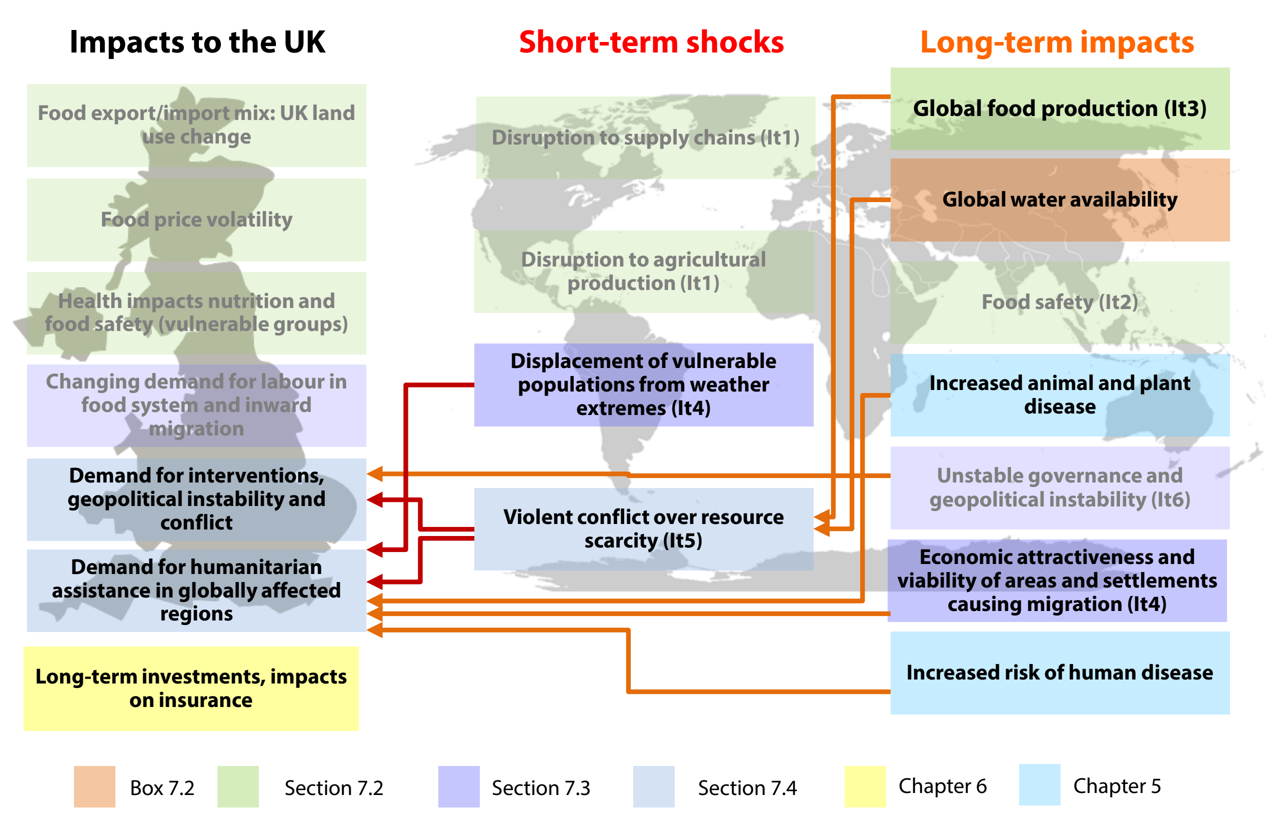
All of these dimensions represent both current and future risks, including:

- an increased demand for humanitarian assistance,
- state failure and violent conflict leading to UK interventions,

- breakdown in international law and governance,
- economic consequences in regions important to UK interests, and
- biosecurity threats that could be transmitted to the UK as well as those that require international co-operation and co-ordination to control.

These risks directly interact with each other and with other dimensions such as changes in migration flows discussed above. As such, risks and impacts are difficult to assess and quantify.

Figure 7.8. Climate drivers, global geopolitical risks and impacts to the UK



Source: CCRA authors.

7.4.2 Conflict, development assistance, biosecurity and international co-operation policies

Several UK government departments have central roles in developing and enforcing international policies related to conflicts, development, biosecurity and international co-operation. These include DFID, the FCO, the MoD, the Home Office and DoH. Other departments play important roles in areas where close international co-operation is needed, such as Defra in relation to EU policy on food and agriculture, DECC on climate change mitigation, and BIS through the UK Trade and Investment agency (UKTI).

International development and aid funds are legislated through the International Development Act (HM Government, 2015b), which stems from Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee (DAC) requirements of which the UK is part (DfID, 2013). The Act requires government expenditure in overseas aid to be at least 0.7% of UK Gross National Income. This target was met in 2013 and 2014 (DfID, 2013, 2015).The main expenditure goes through DfID, as well as through the FCO, MoD, DECC.

The role of climate change as a risk multiplier for development and aid issues is recognised in the International Climate Fund. This has committed £3.87bn over the 2011 – 2016 period. This budget is programmed, thus the timeline of the actual expenditure is different. As a comparison, public international expenditure on climate adaptation is globally about £25 billion per year (OECD, 2015). The fund is managed by DfID, DECC and Defra, and aims to help target countries to adapt to climate change and reduce their emissions. The Government has committed to increase this spending by at least 50%, rising to £5.8bn over the following five years.

The National Security Strategy and Strategic Defence and Security Review 2015 (HM Government, 2015a) also recognises the role of climate change as 'risk multiplier' expected to aggravate existing pressures within and between countries. The UK highlighted climate change as a risk when it chaired the United Nations Security Council in 2007 (Harris, 2012).

Climate change adaptation and links with development aid are recognised in the Strategic Defence and Security Review (2010) and the subsequent Building Stability Overseas Strategy (HM Government, 2011). This strategy aimed to integrate the work on conflict prevention within the actions toward the achievement of the Millennium Development Goals. Until 2015, the main instrument to achieve this was the Conflict Pool, delivered jointly by DfID, FCO and MoD. However, the pool was replaced in 2015 by a Conflict, Stability and Security Fund (CSSF), which has "more of a top-down approach with more NSC [National Security Council] oversight and an emphasis on in-county impact" (FCO, 2015). UK average defence expenditure amounts to tens of billion pounds.[15]

In terms of international law and governance, the UK has tens of thousands of bilateral, multi-lateral agreements and conventions (FCO, 2015). These agreements are needed to maintain the UK's economic interests, such as maintaining open and stable international trade, and also in buffering the risks discussed in this chapter.

Other important international agreements relate to climate change mitigation and adaptation (for example the Paris Agreement of December 2015 and the United Nations Sustainable Development Goals for 2030 (SDGs, United Nations, 2015b), also agreed in 2015). If fulfilled, in practice these agreements would help address many of the drivers of the risks discussed in this chapter, including unsustainable economic development and use of resources, and state fragility to weather extremes. The latter will be influenced by the willingness of states to implement the principles of the Sendai Framework on Disaster Risk Reduction (SDRR) (United Nations, 2015a), including the reporting of progress in managing disaster risks. Neither the SDGs nor the SFDRR are legally binding.

[15] https://data.gov.uk/dataset/uk_defence_statistics

7.4.3 Current and future risks and opportunities

Increased demand for humanitarian and overseas development assistance (It1, It3, It4, It5, It6)

At present, humanitarian assistance is a varying proportion of DfID's expenditure in any year. Unforeseen expenditure arises from weather-related disasters such as Typhoon Haiyan, the recent floods in Pakistan and drought in the Horn of Africa. This expenditure diverts resources from longer-term development and resilience building activity. At present, only around 5% of expenditure on emergency assistance is allocated to disaster risk reduction globally (GHA, 2015). Since the Government has committed to spend 0.7% of Gross National Income on Official Development Assistance (ODA), the capacity of the UK to provide aid overseas is directly linked to the strength of the national economy.

Projections show that the demand for humanitarian assistance will increase, largely due to climate change, by 2030. There is uncertainty in the actual figure that ranges from 32% to 1,600% by 2030 (Webster et al., 2009). If other countries meet this demand, it could lead to the UK's role and influence being diminished internationally. A decline in the UK's relative role globally could lead traditional recipients of UK development assistance in Africa and South Asia to become increasingly reliant on other countries for aid. A number of these recipients are former colonies with traditionally strong ties to the UK through the Commonwealth (PricewaterhouseCoopers, 2013). A core risk to the UK is that countries that have fewer vested interests in global open markets may step in, providing aid in exchange for bilateral agreements, which secure long-term access to land and strategic resources. Failure to respond to humanitarian crises might also have a political impact domestically, for example through public opinion. The Ashdown Review (Ashdown, 2011) of DfID priorities relating to humanitarian assistance suggested that a more pro-active strategy is needed to build resilience in disaster-prone regions. The need for building long -term resilience and coordinating climate change, disaster risk reduction and development policies is underlined by several sources (Royal Society, 2014; United Nations, 2015a; United Nations, 2015b).

An increased demand for humanitarian assistance will result from many of the drivers already analysed in this chapter, namely production shocks, long-term changes in global production patterns, weather-related human displacements, violent conflicts, and biosecurity and disease risks. Having to shift limited UK spending from longer-term development to short-term humanitarian assistance in response to events will undermine efforts to build in-country resilience and, as a consequence, exacerbate the risks discussed elsewhere in this chapter.

State failure, instability and conflict risk (It5)

Fragile states in crisis are unable to provide basic services to their citizens including imposing the rule of law. Failed states have significant consequences for neighbouring states and regions. Recent conflicts in Darfur, Mali and Syria have taken place in the context of weather-related disasters or recovery from drought (Box 7.2; CAP, 2013; Adger et al., 2014; Gleick, 2014; Kelley et al., 2015; Harris et al., 2013; Peters and Mayhew, 2015). While there is significant debate about the relative role of weather-related resource scarcity in conflict, states with weak governing institutions may see greater internal conflict as a consequence of competition between different sectors or increased population stress (e.g. rural communities moving into urban areas in search of jobs after agricultural livelihoods are suppressed).

Instability in global food markets also impacts on security and conflict in fragile states. The Middle East and Sub-Saharan Africa are particularly exposed to volatility in world food markets, and this can have ramifications for how the UK responds to conflict in these regions (MoD, 2014) As discussed in Section 7.1, there is ongoing scientific debate on the influence of climate change and resource scarcity in triggering or amplifying present and recent civil conflicts (e.g. Gledditsch, 2012, and Gleick, 2014, are two examples of diverging views). However, many of the factors that increase the risk of civil war and other armed conflicts are sensitive to climate change (e.g. low per capita incomes) (Adger et al., 2014). The IPCC reports conclude that the role of climate change in conflict is uncertain, but there are significant reasons for concern if climate change affects the livelihood of poor populations, given the strong association of poverty with civil conflict (Adger et al., 2014). In many civil conflicts in the past half-century, resource scarcity has been evident, even if not a triggering factor for conflict. Indeed, the IPCC reports highlight that regions in conflict and post-conflict countries have low adaptive capacity and may themselves be highly vulnerable to future impacts of climate change (Adger et al., 2014).

Future impacts of climate change may exacerbate resource scarcity stresses by displacement of rural communities, reduced availability of food, energy and water to different sections of the population, or increased incidence of disease (putting a subsequent additional strain on health services). In the case of extreme weather, states that are burdened with repair or rebuilding costs associated with environmental disasters may be less capable of providing health, social and security services to their whole population (Smith, 2011).

Competition over water availability and access within states and between communities and different users of water (for example crop irrigation versus livestock watering) has a strong association with physical conflict and a contributory role in internal state instability (see Box 7.2).

Future risks to the UK are three-fold. First, state failure in a given area may require greater proportions of UK (and other) aid to be channelled to humanitarian assistance, reducing the funds available for longer-term economic development and adaptation actions thus failing to address some of the root causes (United Nations, 2015a; United Nations, 2015b). Second, the breakdown of state structures can lead to greater insecurity of trade and transportation through the area. For example, the collapse of state authority in Somalia led to a period of increased piracy in the Indian Ocean that required a large multi-lateral naval mobilisation to suppress it. Analysis of the micro-dynamics of conflict show that observed conflicts can lead to migration. Populations might also be rendered less mobile and effectively trapped in conflict zones (Raleigh, 2011). Finally, in extreme cases, state failure may require military presence by international forces (including from the UK) to control non-state elements including terrorist organisations.

Ongoing assessments by the US security services conclude that climate change will increase the frequency, scale and complexity of future military missions (CNA, 2014; US Department of Defense, 2014). The UK's limited military capability may be challenged by increasing, concurrent, demands for deployment to provide humanitarian assistance, conflict intervention and peace-keeping. In parallel, climate impacts in the UK will also periodically require military assistance, as was necessary during recent flood events. Increased demand for reactive military intervention might detract resources from longer-term, preventive measures, potentially exacerbating the risks.

Breakdown of international law and governance (It6)

The impacts of climate change pose risks to international law and stability by overwhelming the capacity of global institutions to respond to local crises, whether these take the form of civil wars, state failure, disease outbreaks or environmental disasters (Foresight Report, 2011a).

Increased pressure around the world for access to food, energy and water resources, exacerbated by climate change, could lead to an increase of state-led enterprise, resource protectionism and strategic bilateral agreements that secure long-term access to resources at the expense of the global markets upon which UK businesses rely (Paskal, 2009; PricewaterhouseCoopers, 2013; GST, 2014). Such challenges will need strengthened core global governance structures that promote free trade and open markets while also providing a legitimate source of arbitration for disputes. However, such institutions will likely be dependent on their capacity to respond to crises in ways that are perceived to be legitimate.

The impacts of climate change could also increase the risk of attempts to revise established principles of international law and governance. For example, the UN Law of the Sea establishes the economic, territorial and sovereignty rights of coastal states over maritime spaces. Rising sea levels, coastal erosion and the migration of fish stocks may all lead to the disruption of international relations if countries increasingly question the status quo legal order to increase their maritime rights (Paskal, 2009). Similar attempts at revision of use agreements are likely over transboundary resource-sharing agreements (e.g. over fisheries, water usage, see Box 7.2) in response to climate-induced changes in water flows or resource abundance. The adherence of global emission targets discussed at the COP21 (December 2015) will define the future directions of climate change.

Risks to the UK arise through spill-over effects, from increased political tension and even conflict between states. International legal mechanisms and river basin institutions contribute to the transboundary capacity to anticipate and respond to stresses and the ability to manage conflict effectively (Adger et al., 2014). The UK has been actively involved in supporting multi-lateral initiatives to promote institutions for transboundary water management, for example in the Nile and parts of south Asia. Current tensions and rivalry between states in transboundary basins will be significantly challenged by projected regional climate change. The capacity of current conflict resolution mechanisms will also be challenged. There are potential opportunities over shared resources, such as changes in the Arctic providing increased demand for UK maritime services, though many such opportunities are highly uncertain (Box 7.3).

Transmission of global disease risks to the UK (NE9, chapter 3 and PB11, chapter5)

Major disease risks to the UK threaten human, animal and plant health. Climate change may be an important contributor to these risks, either directly (climate change acts on a climate-sensitive disease) or indirectly (climate change acts on another driver of the emergence and spread of diseases, such as land use change or conflict). The risk to the UK arises by two main routes. First, climate change may cause an exotic disease to spread towards and, eventually, into the UK. Second, climate change may trigger disease emergence elsewhere in the world, which then reaches the UK from the international movements of people and goods.

For example, bluetongue is an insect-borne viral disease of wild and domestic ruminants, including cattle and sheep. It was considered an exotic disease in Europe until 1998. Since then, it has repeatedly entered the continent, leading to the deaths of well over a million animals, as well as significant economic losses because of lost opportunities to trade. In 2007 alone, the bluetongue epidemic is estimated to have cost €1.4 billion to the French economy (Tabachnick et al., 2008). The emergence of bluetongue in Europe is associated with the effects of changes to elevated mean temperatures on and the ability of the insects to spread the virus, as well as extreme weather events (Guis et al., 2012). In 2006, following an unprecedented period of hot weather, bluetongue appeared in northern Europe for the first time. It spread to the UK in 2007 in two ways. First, infected insect vectors were able to cross the Channel (Gloster et al., 2008). Second, despite restrictions on the trade in livestock from infected regions of Europe, infected cattle were nevertheless imported (Menzies et al., 2008) (see Chapter 3).

Another example is how global travel and trade are driving the spread of mosquito vectors of human disease. The trade in used car tyres, for example, has helped the Asian tiger mosquito, *Aedes albopictus*, spread to many parts of the world. This mosquito was first found in Europe in 1979 and has now spread over many parts of southern Europe. It is able to transmit both dengue fever and a viral fever called chikungunya. Change in the mean climate will also facilitate the spread of the Asian tiger mosquito towards the UK (Caminade et al., 2012). Movements of vehicles under or across the Channel may facilitate its eventual entry. Outbreaks of Chikungunya in France have been linked to extreme precipitation events (Roiz et al., 2015). The role of climate change in the recent outbreak of the zika virus in central and South America is a subject of active debate. Warmer and wetter conditions facilitate the transmission of mosquito-borne diseases like zika (see Chapter 5).

7.4.4 Current adaptation and policy gaps

As discussed in the previous section, the impacts to the UK from state failure and international conflict affect the UK by increasing the demand for intervention and humanitarian aid. This in turn detracts funds away from building long-term resilience to these risks, such as through promoting sustainable development and addressing state fragility.

The ability of current policies to address these risks therefore depends on whether they build long-term capacity for countries to address state fragility, meet economic development needs, and reduce disaster risks.

The proportion of expenditure in each different development area (including humanitarian aid versus sustainable development) is not regulated, except for the geographical destination (DfID, 2012; House of Commons, 2015). While the pre-2015 Conflict Pool was considered an effective instrument to promote stability in fragile states, there are concerns that the new Conflict, Stability and Security Fund (CSSF) might result in a shift towards more short-term interventions (rapid response) at the expense of long-term resilience and conflict prevention (SaferWorld, 2014). Shifts in development expenditure towards humanitarian aid, in response to events, similarly decreases the focus on improving governance and capacity (House of Commons, 2015; IDC, 2015). The Government disagreed with this point but did not provide evidence to the contrary (HM Government, 2015b). Furthermore, the CSSF is a single-sector intervention, thus may not address systemic issues and their consequences (Ruttinger et al., 2015). There is no data on how UK funds impact on the level of in-country adaptation, or in achieving Sustainable Development Goals or aiding the implementation of the Sendai Framework for Disaster Risk Reduction. Despite the growing recognition of the importance of adaptation (Denton et al., 2014), there are not yet internationally agreed indicators to measure progress in countries (UNEP, 2014). As discussed in section 7.3.5, there is limited scope for unilateral intervention on geopolitical risks. The UK can play an important role in influencing and fostering international goals such as SDG or the application of SFDRR.

As with food security risks, there is a lack of systematic monitoring of the trends and early warning of potential breakdowns in governance, and the threats posed by inter-state rivalry over resources sensitive to climate change. This lack of early warning, as well as shortcomings in planning and implementation, is highlighted in the G7 report 'A new climate for peace' (German G7 Presidency, 2015). The UK's economic interests are widespread and dependent on open and stable international trade. Hence there is a likely benefit for the UK to invest in multi-lateral co-operation to promote long-term stability of international law and governance regimes (such as the UN Law of the Sea) that may be threatened by resource scarcity and state rivalry over resources.

7.5 Conclusions

This chapter shows that the risks to the UK from climate change are broader and more complex than simply those originating within UK territory. The UK is highly integrated into global markets, systems and frameworks through its open economy, interactions with European and global populations, institutions, cultures and economies, and through the movement of goods, services and people. The risks identified in previous chapters will interact with, and are often amplified by, climate change affecting Europe and other parts of the world. UK responses to global risks interact with and can exacerbate challenges and dilemmas in domestic adaptation actions and policies. This is particularly true of the challenges of sustainable food production and land use.

This chapter also highlights that many of the solutions and potential positive opportunities associated with climate change are also highly international in their nature. The role of the European Union and its relationship with the UK is critical, for example, in responding to food system resilience, and in harmonising responses to migration and labour flows that are sensitive to climate impacts within Europe and internationally. There is also significant potential to use the international climate change agenda to improve food systems and health, since altered patterns of food demand that improve health (e.g. reducing obesity) also tend to reduce the carbon footprint of food production.

The risk assessment in this chapter is limited by the predictive ability of models and by the limitations of observed experience. The international dimensions of risk arise through interacting processes and systems, and many of the feedbacks, for example between international trade, food systems and conflict, are not well characterised or understood. While climate change is one of many risks within the spectrum of challenges facing global communities, it is one that is likely to increase in importance as a driver of insecurity, and this will have implications for the UK. For higher levels of warming, and more rapid warming rates, the evidence and models are limited in their ability to predict the future with any confidence, and hence the uncertainty itself becomes a major issue within the international dimensions of risk discussed here. The characterisation of the risks can be improved through targeted research. Focused policy that cuts across all relevant government departments can build resilience, regardless of the uncertainty in future projections.

7.5.1 Priorities for action in the next five years

The risks and opportunities identified in this chapter have been scored according to their urgency, following the method presented in Chapter 2. The three key dimensions of international risk (global food systems, migration and displacement, and geopolitical issues) are inter-related in terms of both causes and consequences. Each of the risks and opportunities identified in this chapter is complex, in the sense of having emergent and interacting properties. Analysis in this area involves scenarios, models and forecasts of the behaviour of actors such as governments, but all analysis involves deep uncertainty. Although limited quantitative assessment is available, evidence indicates that international risks to the UK are already of high magnitude and are likely to increase with further increases in global temperature.

Overarching policy gaps include the lack of strategic cooperation within and between the three dimensions considered: food systems, migration and geopolitical risks. Policy gaps include a lack of coordination between humanitarian, development, trade, foreign, food and security strategies, and the lack of knowledge and data management and its strategic use. In particular, improvements in the global food system need to be achieved by trade policy that supports the role of markets yet builds domestic resilience to price spikes and market shocks. Relying on market responses to manage imbalances in supply and demand is appropriate under standard expected levels of variability but leaves the UK exposed to impacts when markets are under stress. The lack of a unified system or process to understand and manage the role of the UK within global food systems is the principal barrier to the improvement of systemic resilience. In recognition of this, the House of Commons EFRA committee on food security, for example, recommended that Defra appoint a Food Security Coordinator.

Another key priority is for the UK to co-ordinate adaptation to climate change globally, with international partners including the EU. This includes the coordination of development assistance with the EU to reduce migration and conflict risks in other regions; and the development of common strategies and harmonised policies for biosecurity risks, assistance to people displaced due to weather-related extremes in home countries, and on agreed policies with the EU for how countries should respond to variations in food availability and price spikes in global food commodities.

7.5.2 Key research gaps

The priorities for further research identified in this chapter are to:

- Reduce uncertainty in assessments of the risk posed by climate change to major global agricultural commodity producing regions. This includes improving the robustness of assessments through multiple methods, from modelling, to scenario generation, to observational studies, including government responses to spikes and volatility.
- Quantify the covariate nature of risk of multiple food production failures in world regions.
- Surveillance systems to monitor food safety at source and through complex international supply chains.
- Assess national government and other strategic actor behaviour in the face of increased volatility in food access, population movement and conflict risks. The assessment could include, for example, risks associated with foreign direct investment to secure food production and export bans to ensure domestic food availability.
- Characterise and quantify the risks of displacement and of trapped populations arising from weather-related extremes in vulnerable areas worldwide in order to consider the demand for humanitarian assistance as well as the wider risks of political instability.
- Assess the design and potential reform of institutions for global and regional co-operation to avoid and manage instability and resolve disputes arising from climate change, for example

over transboundary water resources, Arctic region impacts, changing access to Exclusive Economic Zones, and risks of state failure.

- Assess the design and potential reform of allocation of funding for humanitarian aid versus long-term sustainable development, including tracking and measuring impacts of long-term development aid in reducing risks of humanitarian crisis.
- Assess the risk posed by abrupt change and climate tipping points to global food production including an assessment of the likelihood, impact and geopolitical consequences of climate change and food insecurity.
- Characterise and quantify food system risks in supply chains, nutrition, and political instability due to extreme weather and climate change.

Annex 7.A Policy tables

Table 7.A1. Food policy framework

Policy reference	UK nation	Key effects of this policy in addressing climate risks	Links to other policies
UK Food Security Strategy The strategy has not yet been published (as 06/16), but the Government response to the EFRA committee report on food security (EFRA, 2014) provides a description on current Government's food security strategy	UK	The objectives of the government food security policy are: 1. Access to a wide variety of markets and an open, rules-based world trading system 2. Sustainable intensification 3. Agri-Tech Strategy.	CAP Agri-Tech strategy AMIS TTIP/WTO, etc.
Northern Ireland food strategic action plan: Going for Growth (Agri-food strategy board 2013)	Northern Ireland	The objectives for achieving food security are: • Growing Market Share • Working Together • Sustainable Growth • Innovation, entrepreneurship and skills • Better regulation • Financing growth • Food fortress. Similarly market-focused as the UK strategy, it also acknowledges a wider role for the Government to give strategic directions.	It should be linked to UK food security strategy.
WAG, Food for Wales, Food from Wales 2010-2020, Food Strategy for Wales (WAG, 2010)	Wales	The pillars for the strategy are: • Market development • Food culture • Sustainability and well-being • Supply chain efficiency • Integration.	It should be linked to UK food security strategy.

Table 7.A1. Food policy framework

		Similarly market-focused as the UK strategy, it puts a larger emphasis on the supply chain.	
Common Agricultural Policy England (2014)[16] Common Agricultural Policy Scotland (2015)[17] Common Agricultural Policy Wales (2015)[18] Common Agricultural Policy Northern Ireland (2014)[19]	England, Scotland, Wales and Northern Ireland	Basic payments, subject to cross-compliance rules, which include the use of Standards of Good Agricultural and Environmental Condition (GAEC) and Statutory Management Requirements (SMR). Additional support, provided to fund restoration, agri-tech and support to business growth. Greening is mandatory and subject to: crop diversification, permanent grassland and ecological focus areas. The schemes are similar among the four UK countries, with some minor differences (e.g. in Scotland, the scheme also introduces a voluntary coupled support aiming to maintain the current level of beef and sheep farmers in particular areas). They influence domestic agricultural production.	

[16] https://www.gov.uk/government/publications/common-agricultural-policy-introduction-to-the-new-cap-schemes
[17] http://www.gov.scot/Topics/farmingrural/Agriculture/CAP/CAP2015
[18] http://gov.wales/docs/drah/publications/140114directpaymentstofarmers-decisionsen.pdf
[19] http://www.dardni.gov.uk/index/grants-and-funding/common-agricultural-policy-reform.htm

Table 7.A1. Food policy framework

HM Government, A UK Strategy for Agricultural Technologies (Agri-tech strategy) (2013)	UK	The strategy aims to 'match the UK world-leading basic research capability with a renewed focus on applied research in order to bring innovations onto farms and raise productivity.'	
Trade in Animals and Related Products (TARP) Regulations 2011 The Trade in Animals and Related Products (Scotland) Regulations 2012 The Trade in Animals and Related Products (Wales) Regulations 2011 The Trade in Animals and Related Products Regulations (Northern Ireland) 2011	England, Scotland, Wales and Northern Ireland	The regulations establish controls on food imported from countries outside the EU.	
The EU Official Controls Regulation 882/2004 The Official Feed and Food Controls (England) Regulations 2009 The Official Feed and Food Controls (Scotland) Regulations 2009 The Official Feed and Food Controls (Wales) Regulations 2009 The Official Feed and Food Controls (Northern Ireland) Regulations 2009	England, Scotland, Wales and Northern Ireland	Main legislation for the control of food not of animal origin entering the UK from non-EU countries.	

Table 7.A1. Food policy framework

EC Regulation 852/2004, the Food Hygiene Regulation	UK	Food imported from non-EU countries must also comply with the food hygiene requirements established by this regulation.	

Source: CCRA analysis.

Table 7.A2. Migration policy framework

Policy reference	UK nation	Key effects of this policy in addressing climate risks	Links to other policies
Labour migration	UK	None	Related to settlement patterns. Labour market effects and service provision.
EU free movement legislation and associated jurisprudence.	UK	None	Related to settlement patterns. Labour market effects and service provision.
Asylum	UK	None	Engagement with phase 1 of the EU's asylum policy (CEAS) establishing minimum standards for asylum applicants, but not further development of the CEAS.
EU Global Approach to Migration and Mobility	EU	The EU's global migration strategy (GAMM) contributed to international discourse on the migration-development and the migration–climate change nexus while, in subsequent follow-up work, making the link between migration and strategies of adaptation to climate change.	Links to UK and EU development, adaptation, poverty reduction and foreign and security policies.
EU European Agenda on Migration (2015)	EU wide	Climate change, persecution, civil war and poverty all identified as possible drivers of displacement.	Links to UK and EU development, adaptation, poverty reduction and foreign and security policies.

Source: CCRA analysis.

Table 7.A3. Geopolitical policy framework

Policy reference	UK nation	Key effects of this policy in addressing climate risks	Links to other policies
International Development Act (2015)	UK	The Act defines the Government expenditure in overseas aid to be at least 0.7% of its gross national income. Current expenditure amounts to about £11Bn, and the 2004-2014 average amounts to over 7Bn[20].	This percentage is a requirement from OECD's Development Assistance Committee (DAC).
International Climate Fund (2011)	UK	A £3.4 billion fund spanning 2011 – 2016. The fund is managed by DFID, DECC and Defra and aims to help target countries to adapt to climate change and reduce their emissions.	
National Security Strategy (HM Government, 2015a)	UK	It recognises the role of climate change as 'risk multiplier' that would aggravate existing pressures within or between countries.	
Strategic Defence and Security Review (2010) and Building Stability Overseas Strategy (HM Government, 2011)	UK	Recognises the links between development, state fragility and conflicts, thus aims to link SDGs and conflict preventions.	National Security Strategy (HM Government, 2015a)
Conflict, Stability and Security Fund (CSSF) (FCO, 2015)	UK	Fund for in-country interventions, to implement the Building Stability Overseas Strategy. In comparison to the previous Conflict Pool, this pool has a more of a top-down approach with a larger oversight from the National Security Council.	Strategic Defence and Security Review (2015) and Building Stability Overseas Strategy (HM Government, 2011). National Security Strategy (HM Government, 2015a)

[20] https://www.gov.uk/government/organisations/department-for-international-development/about/statistics

Table 7.A3. Geopolitical policy framework

The UK has tens of thousands of bilateral, multi-lateral agreements and conventions (FCO, 2015)	UK	These agreements are relevant to maintain UK economic interests, such as maintaining an open and stable international trade. These agreements have also a role in buffering the other risks discussed in this chapter, including flood safety, migration, and geopolitical risks.	Food safety policies EU migration agreements International Development Act Common Agricultural Policies Etc.

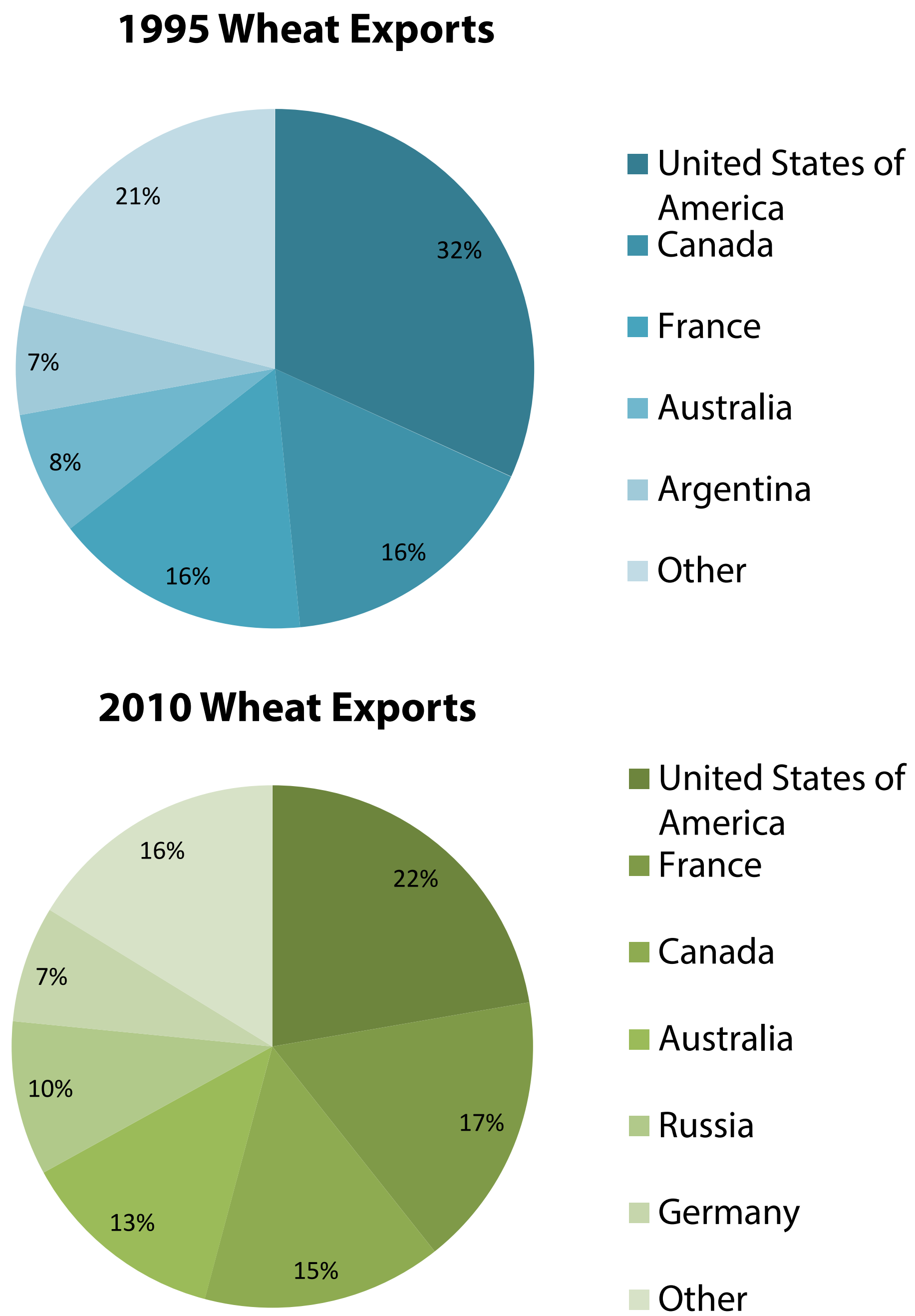
Source: CCRA analysis.

Annex 7.B Overview of global food production and trade

For major agricultural commodities, a significant proportion of total global production is now traded internationally (Liapis, 2012). Trade flow in wheat and rice has more than doubled in recent decades (Puma et al., 2015).

In Figure 7.B1, the share of world exports for the main wheat exporters for 1995 is compared with that for 2010, highlighting how these shares have changed over time: taken together, in 2010, Russia and the Ukraine accounted for 11% of world wheat exports with the role of the more 'established' suppliers declining: the US accounted for less than 20% of world wheat exports in 2010. On the one hand, there is a positive dimension to this insofar as world wheat exports are now more diversified. On the other hand, there is an issue of reliability from the new export suppliers given the incidence of weather-related shortfalls in recent years combined with the use of export taxes by the Ukraine and Russia to prioritise domestic food availability (Fellmann et al., 2014).

Figure 7.B1. Concentration and changing structure of world wheat exports: 1995 and 2010

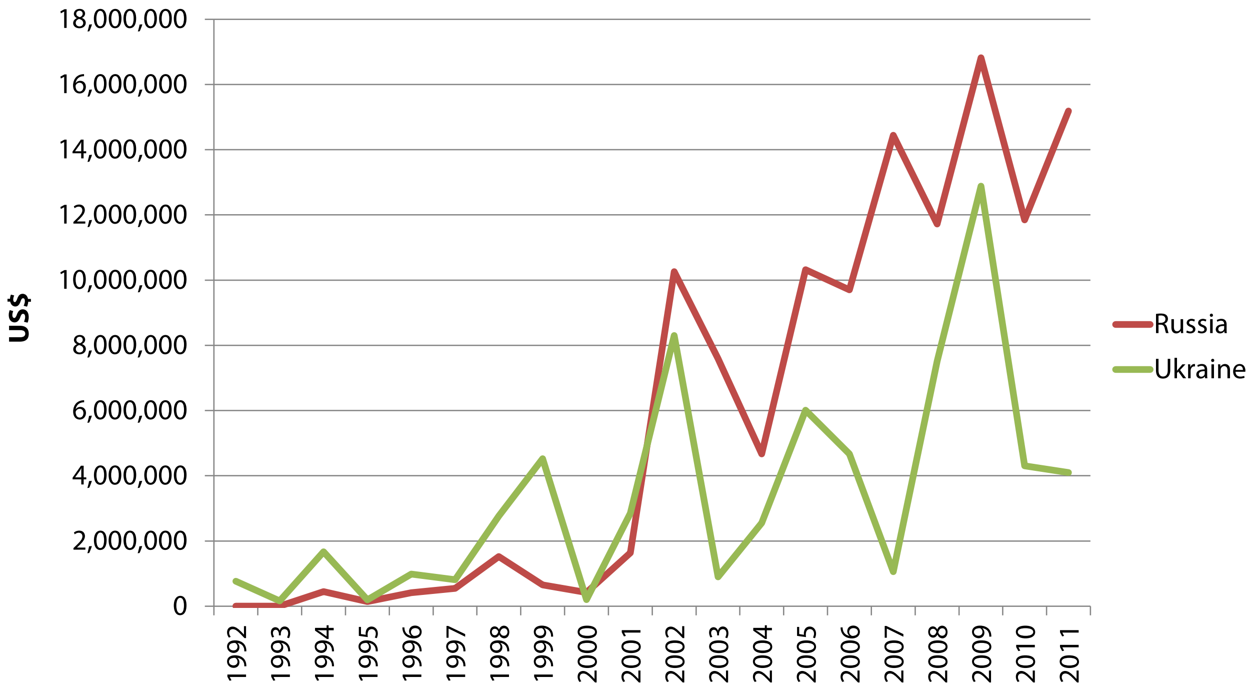


Source: FAOSTAT data, quantities of wheat exports by country.[21]

[21] http://faostat.fao.org/site/342/default.aspx

Figure 7.B2 illustrates the growing importance of Russia and the Ukraine as exporters to world markets since the early 1990s. The figure also highlights the volatility of exports from these countries that could arise due to the combination of climate-related events and associated policy responses.

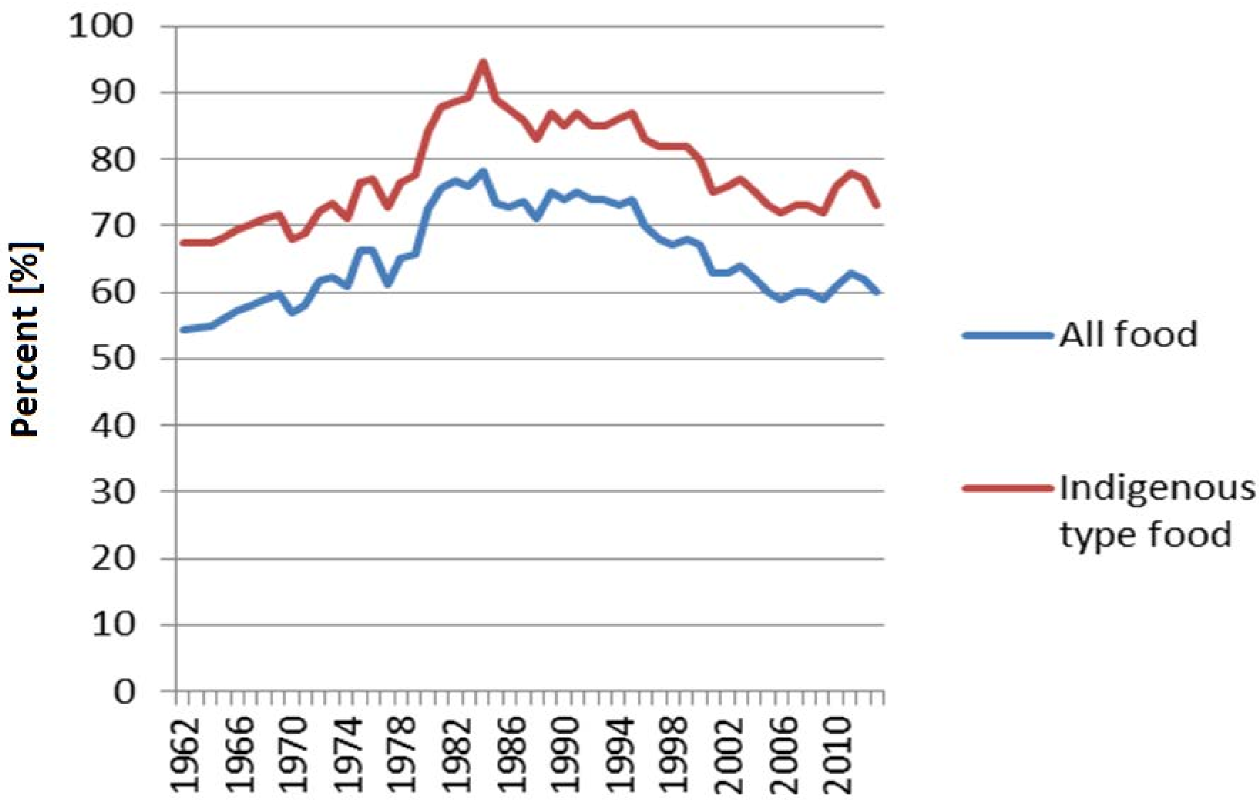
Figure 7.B2. Russia and Ukraine in world wheat markets, 1992 – 2011



Source: FAOSTAT data http://faostat.fao.org/

UK food production, export and import patterns have changed since the end of the last century. For example, UK self-sufficiency was 60% in 2013 from a high of around 90% in the early 1980s (Figure 7.B3). These changes reflect structural change in the economy over time and also changing priorities of agricultural support policy in the EU. Second, the supply of commercial food in the UK is increasingly based on 'just-in-time' delivery; the majority of food stock levels have fallen during the last five years (Defra, 2015b).

Figure 7.B3. UK Food Self-Sufficiency, 1956 – 2013



Source: Defra (2012c).

The UK takes advantage of international trade for both imports and exports: 7% of total exports (£18.9 billion), and 10% of total imports (£40.2 billion) are of agri-food products[22]. Its principal trading partner is the EU, but the UK import from 168 countries in total (Defra, 2012a). Self-sufficiency can be calculated in different ways:

- Using farm-gate values of total production, we are 53% self-sufficient[23];
- If we subtract exports, we are 62% self-sufficient, and
- For consumption of food that we produce locally, we are 78% self-sufficient[24].

The difference between the first two highlights the difference between what we produce and what we use. For example, we produce about 781kT of pork, export about 183kT and import about 729kT[25]. If we divide what we produce by our use (production minus exports plus imports) we are 59% self-sufficient, whereas if we divide what we produce and do not export by what we use we are 45%. Most of what we export and import is not raw agricultural produce but

[22] http://www.wto.org/statistics
[23] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/183302/foodpocketbook-2012edition-09apr2013.pdf
[24] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/208436/auk-2012-25jun13.pdf
[25] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/208436/auk-2012-25jun13.pdf

processed food and drink (of the £40 billion of imports, £14.4 billion is highly and £17.8 billion is lightly processed). The largest categories for imports are fruit and vegetables, meat and drinks; and the largest export categories are beverages, cereals, meat and fish.

UK imports tend to be highly concentrated for a range of key commodities. For example, around 85% of wheat imports to the UK are sourced from the EU (approximately 50% of the total imports), Canada (34%) and the US (1%). Similarly high levels of concentration across import sources are evident for other commodity groups though the trading countries will differ. Brazil accounts for around 75% of UK soybean imports, with the remaining 25% being imported from elsewhere. Soybean is important for animal production.

Annex 7.C Climate impacts: from global food production to world prices to domestic prices

The complex nature of the global food pricing system means that, in gauging the risks to the UK associated with these extreme climate events, it is important to account for not just the magnitude of the production shocks but also how they interact with other short-term drivers of world food prices. While we can consider the impact of extreme events on prices and trade, the nature of the price dynamics associated with extreme climate events will likely differ and, by extension, so too will the appropriate action to counter the risks associated with these events.

Global food prices are a key factor in determining the impacts of climate change on UK food security. The evidence from economic models for price increases over the coming decades is mixed, while post-2050 climate change is expected to result in higher real food prices (AR5 Chapter 7). Increasing prices imply reduced access for the poorest. However, the economic models used for these assessments are (of necessity) general equilibrium models, which cannot account for price fluctuations due to production shocks or other causes. Similarly, assessments of UK impacts (PricewaterhouseCoopers, 2013) have used total imports as the metric for availability, without accounting for any increased imports resulting from high demand.

Extreme climate events impacts on the food system

Impacts on production

The other dimension linking climate to food security is the impact on production shocks associated with extreme climate events such as droughts, heatwaves, flooding, cyclones and so on. As Schmidhuber and Tubiello (2007) note, while most modelling efforts focus on mean effects over a relatively long time period, the shorter-run impacts associated with extreme climate events will have a more immediate impact on food security. To provide some perspective on extreme climate events, the WMO has noted in its recent report, the number of extreme events has increased over the last decade and has been associated with heatwaves, drought, flooding, etc. (WMO, 2013). While there is some debate as to whether the rising incidence of extreme climate events are associated with climate change, it is nevertheless the case that the immediacy of extreme climate events, especially if they have increasing incidence in future years, will have a more immediate impact on the UK, both in terms of the economic impact and how policymakers respond both in the UK and elsewhere.

Impacts on world prices

The emphasis of recent research on climate and food security has primarily focused on evaluating long-run effects, i.e. estimates of price changes through to 2050; research on the specific effect of extreme climate events on the relatively short-run impact on world agricultural prices is generally lacking. Nelson et al. (2010) is an exception to this where they simulate the effect of an extended drought in South-East Asia. The risks to the UK associated with production shocks associated with extreme events can result in a different perspective on the impact of world food prices, the interplay between climate events and other factors, and how the UK government should respond to ameliorate this risk.

While it is clear that a production shock will drive world prices up, the magnitude of the effect will depend on the interaction of the extreme climate event with other factors. As noted above, the disruption to global production need not be significant enough to result in a price spike.

There are two important factors to account for, given the recent experience of the commodity price spikes of 2007 – 2008 and 2011. First, foreign governments will not be immune to prioritising domestic issues over global issues with government decisions over trade policy choices in face of rising world prices being a key factor to recent price spikes (see Martin and Anderson, 2012).

Second, the effect of a production shortfall on the world will depend on the availability of stocks. The experience of the recent price spikes was that stocks have decreased in comparison with the demand over the 2000s. This reduced the capability to make up for commodity shortfalls.

In other words, the scarcer a good is, the higher its price will be (all other factors that determine price assumed to remain constant). The change in a given year's production will affect the price. The effect of a given year's production on the price will be less if there are high stocks of that produce. Similarly, low stocks exacerbate the effect of a production shock on price changes.

In sum, the concern for the UK about extreme climate events is not just that they will happen and may happen with increasing frequency, which will have the potential to make world prices more volatile, but the extent of the world price change will depend on the (global) availability of stocks and how foreign governments respond. These issues are important in assessing the impact on the UK and also have implications for the policy space for the UK government.

Long-run climate change impacts

Impacts on production

Climate modellers have focused on the impact of climate change on yields over a 30 – 40 year period using biophysical–economic models that can identify the potential impact of climate change on productivity and production, and identify the geographical impact of these changes across broadly defined regional groupings and the resulting effect on net trade and world prices for key agricultural commodities.[26] These effects are contingent on assumptions made about climate change mitigation (ranging from the no mitigation effect through to full mitigation) as well as defining the baseline related to other demand and supply drivers which will determine production changes and the effect on prices over the long run; these are discussed below. The modelling efforts differ in specification, the choice of variables to calibrate the models (e.g. price responsiveness of consumers and producers) and assumptions about the baseline scenarios. The specification of these models adds to the uncertainty associated with gauging the effects of climate change on food security.

Nelson et al. (2014) provide a useful assessment of alternative modelling approaches and consider different climate scenarios. Employing nine modelling approaches, they consider common baseline scenarios such that the differences in the estimates lie in the details of the models being employed. The overwhelming assessment is that (area-weighted) global yields will fall, though the impact varies by crop and assumptions about CO_2 fertilisation. The significance of CO_2 fertilisation on the yield effect was also highlighted by Mueller and Binder (2015): they show that with no CO_2 fertilisation, the (global) mean effect on yields will be a decline of around -6.5%; with full CO_2 fertilisation, the mean effect on yields is an increase of around 13%. On the other hand, carbon dioxide negatively affects the protein content of most crops (Taub et al.,

[26] Some models extend the estimate of price effects beyond 2050.

2008), reducing the nutritional quality of the final food (Blumenthal et al., 1996; Fernando et al., 2012). Interactions with temperature can further reduce the protein content (Bai et al., 2005) and the subsequent quality of the bread.

The yield effects also differ across regions; for example, Nelson et al. (2014) show that, even when the global mean effect is close to zero, some regions/countries experience an increase in yields; similar variations across regions are reported in Mueller and Binder (2010). Taking the productivity effect together with the area effect, climate change will have varying effects on agricultural production across regions and, in turn, trade. In the case of the latter, the pattern of global agricultural trade could change with some countries/regions switching from being net exporters to net importers and vice versa. In sum, the effect of climate change on the global food sector will not only impact on prices but also on the geography of production and trade; both of these have implications for assessing the potential risks that the UK is likely to face.[27]

Box 7.C1. Robustness of evidence for changes in growing areas

Numerous modelling studies have used multi-decadal climate change simulations to assess the impacts on crop yields. At the global scale, uncertainty is relatively low. The most comprehensive meta-analysis to date (Challinor et al., 2014a) found, in the absence of agronomic adaptation, reductions in global-scale aggregate yields of maize and wheat from one degree of local warming. Confidence in these global results is reasonably high, since they are consistent with historical climate-induced yield changes (Bruckner et al., 2014). At the sub-global scale, projected reductions in yield in tropical regions are greater than those in temperate regions. Vulnerability to drought is also demonstrably greater in tropical regions (Simelton et al., 2012).

Despite some certainty in the global-scale picture, significant uncertainties exist when examining individual countries. Yields in any one location will be affected by changing patterns of heat stress, drought and flooding. Heat stress is the most predictable of these factors, with projections for the end of the century showing increases in heat stress on global maize, wheat, rice and soybean (e. g. Teixeira et al., 2011).

The evidence for the robustness of climate change impact projections comes increasingly from detection and attribution. This can be carried out at large or small scales. Fisheries, which are particularly suited to global analyses, show a clear impact of warming: an increase in warmer water species captured at high latitudes, and a decrease of sub-tropical species at tropical latitudes (Cheung et al., 2013). At smaller scales, water and food insecurity associated with climate change have been detected in many subsistence farming regions (Hofmeijer et al., 2012).

There is robust evidence for negative effects of increased temperature on feed intake, reproduction, performance and pathogen geographical ranges for livestock (Adger et al., 2014).

Climate change will alter the global distribution of pests and diseases. Evidence of temperature-induced changes already exists, for example in the US, where a change in pesticide use across latitudinal gradients has been detected (Ziska, 2014). While models for projecting future prevalence do exist (e.g. Garrett et al., 2013), there are significant uncertainties (Meynard et al., 2013).

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[27] To underpin the climate change effect across regions and crops, Lobell et al. (2011) show that climate change is already affecting yields: based on the period 1980 – 2008, wheat yields globally declined of approximately 5% due to climate change; but for Russia, the yield decrease has been estimated closer to 20% compared with a marginal increase in yields in the US. For soy, mean yields have declined by around 2% with increases in Argentina being largely offset by decreases in Brazil and Paraguay.

Impacts on world prices

The impact of climate change via the productivity (yield) effect will depend on the role of other long-run drivers of agricultural commodity prices. These will occur on both the demand and supply side. On the demand side, the two main drivers are population growth and income growth. With respect to the former, with the world population increasing towards 10 billion, demand pressures will clearly increase but that is not the only factor: income growth particularly in South and East Asia will increase demand, but for more processed food. This has two effects: first, the increased demand will be a less efficient convertor of basic calories. Second, as average income increases consumers, on average, become less sensitive to price changes, so that increases in prices do not have as big a dampening effect on demand. However, this analysis is based on average: it does not take into account equity issues when there is already a vulnerable population; this is also the case in the UK.

Demand-side drivers have also to be considered against the influence of supply-side drivers, essentially total factor productivity. Total factor productivity has increased in recent years and there is some dispute as to whether the effect of total factor productivity will outstrip the demand-side factors noted above. Taking the demand and supply drivers of world food prices together will determine the underlying baseline for the effect of climate change on world prices. Most research to date (with some exceptions) has emphasised the dominance of demand-side factors, such that the baseline for addressing the long-run impact of climate change comes against the background of a rising trend in world prices.

The effect of climate on yield and production will be reflected in a change in the trend in world prices. On the assumption of inadequate mitigation, it is broadly anticipated that yields will fall, production patterns will change and world prices will rise, as discussed above. With reference to the climate–food modelling approaches assessed by Nelson et al. (2014), there is a wide range of estimates of the weighted average price change across five crops (coarse grains, oilseeds, rice, sugar and wheat) through to 2050. These depend on the climate change scenario but there is also significant variation across models on what the impact on prices will be, even given the common scenarios and common assumptions about baseline trends.

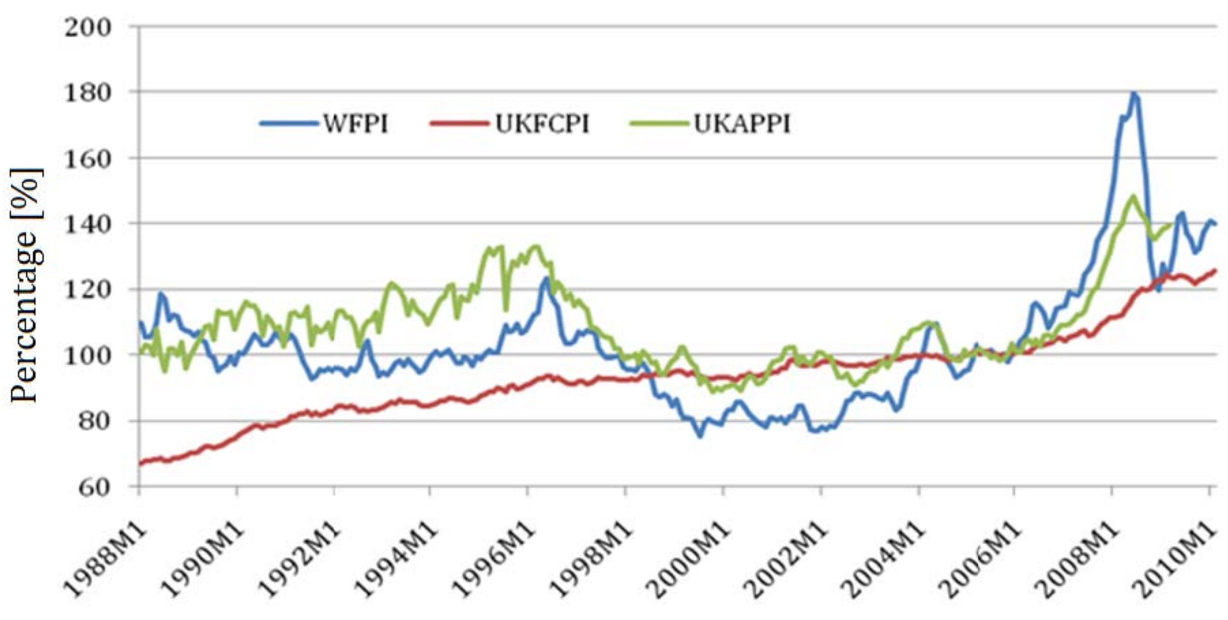
Impacts on international trade

Focusing on the world price impacts due to climate change is a useful shorthand for summarising the global impact of climate change on world agriculture. Changes in yield, production and net trade across different regions will be reflected in the market clearing mechanisms that accounts for these changes i.e. the world price. But changes in trade patterns will also matter and will be an added dimension of the effect on the UK if the current profile of trade in international food products changes. The effect on trade patterns is highlighted in the long-run assessments of climate change. Nelson et al. (2010) provide a review of these potential effects: for developed countries, they report that climate change effects will reduce the export potential for wheat exports (and similarly for maize), while, in the case of rice, climate change adds to the import demand from developed countries. For low-income countries, net exporters of rice turn into net importers. One potential issue for the UK given the changing profile of world trade that could arise with climate change is how other countries respond to their net trade status and how this ties with their own food security concerns.

From world prices to domestic prices

Both the long-run and short-run effects of climate change in the world food sector are manifested through the effects on world prices, and by extension, the impact of world prices depends on domestic price changes through the price transmission effect. It is this latter mechanism which will determine the distributional impact within the UK. Availability may also matter (given the evidence related to the UK's self-sufficiency and main trading partners) but given that global production shortfalls do not have to be that great to have a major impact on world prices as noted above, the most obvious mechanism for thinking about the links between climate change and food security is through world prices. However, in the context of the other drivers of prices, the extent of the price rise and what the relative importance of climate change effects on prices will be are unclear in these assessments. In terms of considering the consequences for the UK, it is important to recognise that world price changes do not necessarily translate 1:1 into corresponding changes in domestic prices. In short, depending on whether you are focusing on domestic farm-gate prices or domestic retail prices, price behaviour can be quite different to world prices. This is evident from Figure 7.C1, which shows world wheat food prices, UK retail prices and UK domestic producer prices; clearly, the dynamics of world price changes differs from that of price changes in the UK depending on which part of the food chain you are considering.

Figure 7.C1. World food prices (WFPI), UK retail prices (UKFCPI) and UK domestic producer prices (UKAPPI) as percentage change compared to 2005



Source: Office for National Statistics (ONS), Inflation and price indices.[28]

[28] https://www.ons.gov.uk/economy/inflationandpriceindices

The mechanism that determines the price effects within the UK when world market prices change is related to **price transmission**.

There are two dimensions to this:

1. Horizontal price transmission, which is the price change for the comparable commodity produced domestically relative to the world price. The data from Figure 7.C1 indicates that this horizontal price effect is strong.
2. Vertical price transmission, which relates to the price changes of the processed food following a change on world (or domestic farm-gate) prices of the raw ingredients. The impact of a production shock due to climate change affecting raw food on UK-consumed processed food will be muted. This is because the raw commodity represents a small share of the cost of the final processed food the consumer buys at retail. For example, if wheat represents 20% of the cost share of bread, the rise in consumer prices will 'only' be 20% of the change in world wheat prices. The structure of the food chain will have the potential to dampen any effect due to production shocks, i.e. even with a cost share of 20%, the effect on bread prices at retail will be less than 20% (Lloyd et al., 2015a). The experience of the UK following recent events on world markets suggest that the UK was more exposed to world price shocks relative to other EU Member States (see Lloyd et al., 2015); the effect on UK consumers may be muted but the impact was greater compared with other members of the EU highlighting the UK's exposure to events from world markets. Even though price shocks may be reduced as they pass through from world markets to domestic retail prices, the poorest groups are more affected by these changes. Although expenditure on food represents around 11% of total expenditure, for the lowest quintiles, the share of food expenditure is closer to 16% (Defra, 2014b). As with estimates on global food security, it is the poorest who likely suffer most from climate change.

Annex 7.D Extreme weather events and their impact on global food system chokepoints

Climate change will have a fundamental, widespread and long-term impact on the physical structures on which food trade depends, both directly and indirectly. The heightened frequency, intensity and impact of extreme weather events will result in more regular and more prolonged interruptions to transport infrastructure and trade chokepoints, risking food price volatility and the dislocation of food supply (Bailey and Wellesley, in press).

Table 7.D1. Impact on global food system chokepoints from extreme weather events

Infrastructural chokepoint	Extreme weather event	Degree of confidence	Share of UK/global food trade at risk	Nature of disruption to infrastructural chokepoint	Precedent	Further reading
Mississippi River System	Drought	IPCC: high confidence in more intense droughts in North America (AR5 WGII – North America). Predication that low water levels during droughts will pose a growing threat to the reliability of inland navigation (AR5 WGII – North America).	10% of UK soy imports and just under 30% of global soy supply is produced in the US, the majority of which travels to port along the Mississippi River and its tributaries.	Low water levels cause navigational challenges, necessitating restrictions on the number of barges on the waterways and on the maximum draught of those barges.	**2012-13**. Drought in the upper Midwest prompted the introduction of load restrictions.	Rizzo, J. (2013): 'How Drought on Mississippi River Impacts You', 1 February 2013, *National Geographic*, http://news.nationalgeographic.com/news/2012/12/121207-nation-mississippi-river-drought-environment-economy/
United States Gulf coast ports	Storm surge	IPCC: projection that sea-level rise of one metre combined with a seven-metre storm surge could flood over half of roads, waterways and railways in the Gulf Coast area (AR5 WGII – North America).	The US imports over 20% of the UK's maize exports, half of which enter the country via the Gulf Coast ports. A sixth of global soy supply is shipped from these same ports each year.	Severe damage to inundated port infrastructure risks slowing operations for a sustained period. Extreme storm surges can cause the Mississippi River to flow backwards temporarily, causing damage to barges and to locks and dams upstream.	**2005.** Hurricane Katrina caused a storm surge along the Gulf Coast that killed over 1,500 people and flooded 80% of New Orleans in up to six metres of water.	US National Oceanographic and Atmospheric Administration (undated): 'Storm Surge and Coastal Inundation'.

Table 7.7. Impact on global food system chokepoints from extreme weather events

Panama Canal	El Niño	IPCC: High confidence that ENSO will continue to be the dominant mode of natural climate variability in the 21st century (AR5 WGI – Climate Phenomena and their Relevance for Future Regional Climate Change).	5% of UK cereal imports, and over 10% of global cereal supply, transits the Panama Canal each year.	Long periods of dry weather brought by a strong El Niño see water levels drop in the Gatun and Miraflores Lakes, restricting the passage through the canal of large vessels.	**2016.** Depth restrictions were applied to ships transiting the Canal owing to low water levels brought by El Niño, affecting nearly a fifth of vessels using the Canal.	Sohns, A. (2015): 'Does Climate Change Threaten the Future of the Panama Canal?', *Huffington Post*, 11 December 2015, www.huffingtonpost.com/antonia-sohns/does-climate-change-threa_b_8519642.html
Brazilian ports	Landslide	IPCC: Medium confidence in more frequent extreme rainfall events, bringing landslides and flash floods (AR5 WGII – Central and South America). Extreme flooding events along the southern coast of Brazil and the northern coast of Argentina may become more frequent (AR5 WGII – Central and South America).	A fifth of the UK's imported soy, and over 30% of global soy exports, is sourced from Brazil, the vast majority of which is shipped from these ports. 7% of UK fertilizer exports are destined for the same region.	Landslides prompted by unusually heavy rainfall may render main roads impassable and leave debris within the port area itself, interrupting loading and unloading operations.	**2008**. Landslides closed the Port of Paranaguá, contributing to economic losses of US$ 350 million.	FBDS/Lloyd's (undated): *Climate Change and Extreme Events in Brazil*, www.lloyds.com/~/media/lloyds/reports/360/360%20climate%20reports/fbdsreportonbrazilclimatechangeenglish.pdf
Suez Canal	Strong winds	IPCC: medium confidence that changes to surface wind and waves, sea level, and storm intensity will increase the vulnerability of the shipping industry (WGII – The Ocean).	57% of UK rice imports, and a sixth of UK barley exports, pass through the Suez Canal. A detour around the Cape of Good Hope would add 10 days' sailing time between the Arabian Gulf and the UK.	Strong winds bring dangerous sailing conditions, and may also drop debris along the canal, slowing traffic while obstacles are cleared.	**2015**. Canal closed owing to strong winds for a number of days.	Al Arabiya News (2015): 'Storm Yohan lashes Mideast, shuts Suez Canal', 12 February 2015, http://english.alarabiya.net/en/News/middle-east/2015/02/12/Storm-Yohan-lashes-Mideast-shuts-Suez-Canal-.html

Table 7.7. Impact on global food system chokepoints from extreme weather events

Malacca Straits	Haze	Haze in Southeast Asia, the result of forest fires in Indonesia, is exacerbated by a strong El Niño event. IPCC has high confidence that ENSO will continue to have a formative effect on climate variability throughout this century (see above).	8% of UK rice imports, and nearly a quarter of global rice trade, is shipped through the Straits of Malacca.	Poor visibility renders navigation through the busy waterway difficult and heightens the risk of collision between vessels,.	**2013.** Forest fires in drought-hit Indonesia caused a smoky haze to spread across the Malacca Straits, prompting the Singapore Shipping Association to warn of potential collisions owing to dangerous conditions.	Marine Executive (2013): 'Singapore Gravely Concerned About Indonesian Haze Impairing Ship Navigation', 21 June 2013, www.maritime-executive.com/article/Singapore-Gravely-Concerned-About-Indonesian-Haze-Impairing-Ship-Navigation-2013-06-21
Indian Subcontinent ports	Floods	IPCC: high confidence that extreme climate events, including floods, will have an increasing impact on human health and security in Asia (AR5 WGII – Asia). Observed trend of increasingly frequent extreme weather events in South Asia (AR5 WGII – Asia).	The UK sources around a third of its rice from India, and a further sixth from Pakistan. Together, the two countries account for 35% of global rice exports.	Inundation of the roads and railways leading to major ports will cause delays to the loading and unloading of vessels. Resulting delays, and damage to storage infrastructure at the port, risk the stranding of perishable assets. Severe flooding may cause damage to port infrastructure and superstructure that takes weeks or even months to repair.	**2011.** Severe flooding in the port of Karachi, and of the roads, railways and bridges surrounding the port, interrupted the export and import of goods for a period of months	Al Jazeera (2011): 'Flooding cripples southern Pakistan', 14 September 2011, www.aljazeera.com/news/asia/2011/09/201191372523868866.html

Source: Bailey and Wellesley (in press).

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