International Impacts of Climate Change on the UK

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Introduction

The primary objective of this report is to scope out the ways in which the impacts of climate change in other countries will affect the UK[2], and the implications that this will have for the UK's adaptation policies. In order to identify the likely potential dimensions of such policies, an initial assessment of the potential size of these risks and benefits is also provided.

The initiative for this scoping exercise derives from the fact that the world is currently characterized by a high degree of international inter-dependence, whether in the form of international trade flows, expanding human diaspora, or other forms of economic, social and cultural integration. Consequently, it is to be expected that climate change impacts in one geographical region may be transmitted by these inter-dependencies to other regions. Since the UK is a particularly open economy, with a population comprised of sizeable ethnic groups originating from a number of world regions, the likelihood of it being susceptible to any secondary effects resulting from international climate change impacts is thought to be high. Furthermore, since most global climate change impact assessments stress that the more severe impacts are likely to occur outside of Europe, it can be assumed that the international effects of climate change impacts in the UK are small compared to the effects of international impacts on the UK.

Most national climate change impact studies have focused on the direct impacts within the countries' geographical borders. The recent study on Sweden[3] is one of the few exceptions to this rule, though its discussion of the impacts of international climate change on Sweden is purely qualitative. This scoping study aims to identify the breadth of possible impacts and indicate which impacts may be prioritized in future research, including the UK Climate Change Risk Assessment.

An initial list of the types of international climate change impacts that may have secondary effects on the UK include:

a) impacts on economic, and other, resources within a country or world region that may lead to changes in trade conditions, with associated implications for UK terms of trade with that country/region;

b) impacts on economic, and other, resources within a country or world region that may potentially lead to internal or external conflicts, with security implications for the UK;

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[2] In this report we use the simplifying term "the UK" to represent the interests of the citizens of the UK.

[3] Swedish Government Official Report. SOU 2007:60. Sweden Facing Climate Change – threats and opportunities. Final report from the Swedish Commission on Climate & Vulnerability

c) impacts on economic, and other, resources within a country or world region that may lead to movement of these resources, with associated pressures on e.g. UK migration policy

d) Wider macro-economic effects associated with one, or a combination, of the above.

With these categories in mind we can construct a simple taxonomy of the transmission mechanisms by which international impacts are borne by UK citizens. This is presented in Table 1. For ease of presentation the impact forms are represented separately. In reality, of course, each transmission mechanism is likely to result in a range of impact forms. For example, an increase in the price of imported foodstuffs is likely to result in a change in the business environment for the food processing sector that has adverse effects on employment in that sector, company profits within the sector, and an increase in food prices faced by domestic consumers, the degree to which the impact is spread over these different forms being dictated by the market conditions in respective product and factor markets.

It should also be noted that the operation of the transmission mechanisms are in themselves a form of adaptation. Whilst the price mechanism supplies information for economic agents to react according to their preferences, (autonomous adaptation), financial support is a reactive, planned, form of adaptation that – in effect – is designed to prevent autonomous human adaptation through, e.g. migration or resource conflict.

Table 1 also serves to highlight the fact that the effects on the UK as a result of climate change elsewhere in the world should not be viewed solely in economic terms; there may be ethical or geo-political reasons to alleviate adverse consequences of such climate change.

Table 1. International Climate Change Impacts – Mechanisms for transmission to UK

Transmission mechanism	UK Impact form	Example
Δ in quantity/quality of traded product → price mechanism	Consumer Labour force	Higher imported food product prices Higher imported raw material prices leading to loss of competitiveness in UK manufacturing
Δ in vulnerability of production and business operations → price mechanism	Producer/Share-holder	Built infrastructure exposed to increased flood risk results in higher price of insurance cover
Public/voluntary financial support for humanitarian & strategic interventions → public good mechanism	Tax payer	Aid to Climate change-induced drought regions
Δ in number of people/other species in UK → physical mechanism	Producer; Labour force; Tax payer	Tourism; Migration

The remainder of this report is presented in three sections. The next section, (Section 2), identifies the main sectoral climate change impacts projected to occur internationally, that may result in secondary impacts in the UK. Whilst there are a number of ways in which impacts can be classified - e.g. on the basis of climatic variable; mean and extreme weather events; short term or long term, etc., here we use the sectoral-type split adopted in many analyses, including the IPCC AR4 reports. Our assessment identifies the geographical region in which the primary impact is projected to occur, the relevant transmission mechanism and the possible forms of adaptation response that may be considered by UK stakeholders. To the extent that it is possible, we give an indication of the size of potential risk to the UK. Whilst the impacts identified may, to some extent, be generic to a number of other countries – for example, those in Northern Europe - the assessment also highlights the degree to which they are unique to the UK, and so may require a unilateral, rather than multilateral, response.

Section 3 assesses certain aspects of those impacts likely to be particularly resonant to the UK in more depth. Specifically, those impacts associated with price changes in the agricultural and financial markets are considered, reflecting our relatively high dependence on imported foodstuffs and strength in the global financial services sector, respectively. We also discuss two responses to international climate change impacts – conflict and migration – which are often raised as specters that may threaten the UK, and UK interests, as a consequence of climate change. Finally, section 4 provides a synthesis of our findings and outlines some initial conclusions and suggestions for areas of future research. It is immediately apparent, for example, when looking at the relevant literature that the existing evidence base is both very limited and primarily qualitative. It is also obvious that other, socio-economic, change is often likely to be at least as important in determining the extent to which climate change impacts result in welfare changes. Effective adaptation responses are therefore likely to depend on being considered within the wider context of overall socio-economic development.

Section 2: Outline of International Impacts on the UK: Sectoral Assessment

The impacts of climate change may have indirect effects on the UK in a number of ways. This sub-section presents an initial scoping of international climate change impacts from a sectoral perspective. Where possible, the impact assessment is accompanied by an initial indication of the potential adaptation actions that may be pursued by the UK actors involved.

Table 2, below, provides an overview of the main sectoral impacts considered, their climatic sources, and principal uncertainties, as well as their cross-sectoral linkages. It is stressed that the impacts outlined are indicative only; the list does not purport to be comprehensive. The climate change impacts ascribed to climate sources in column 2 of the table are described in outline whilst indicating how they are likely to manifest themselves in the UK. As suggested above, the impacts are most directly manifest in the consequences they have for UK-owned business operations that either take place in the world region projected to be impacted by a climatic change or that rely on

inputs from supply chain operations located in these regions, and the UK government and its agencies that have responsibility for international development and/or international security objectives.

Column 3 outlines a number of broadly defined adaptation actions that businesses or the UK government could undertake or encourage local actors to take. In a number of cases, the focus is on development of adaptive capacity within the country, encouraged by international development assistance. This suggestion should be regarded as a complement to more specific adaptation options designed to address climate change impacts more directly.

The cross-sectoral linkages identified in Column 4 in many instances echoes the need for adaptive capacity and vulnerability reduction to be facilitated by patterns of economic development that are more appropriate to a future under climate change. For instance, the health of UK business operations is likely to be determined by the way in which transport and energy infrastructure, ecosystems and water resources are developed and managed within a broader socio-economic context. In this respect, the classification of climate change impacts by sectors in the way defined in this table is artificial and diverts attention from the holistic way in which they should better be addressed. As an example, it should be obvious that water resources and ecosystem services are inputs - or preconditions to - many forms of human activity in a region.

Column 5 serves to highlight the fact that the projected impacts outlined remain highly uncertain given the present uncertainties in the climate science that underlies the projected changes in regional climate change and individual climatic variables. This uncertainty is exacerbated by those inherent in projecting the pattern of future regional and global socio-economic development which – in a number of instances – is indicated to dominate changes in climate, and its impacts. More detail on the geographical disaggregation of the impacts is provided in the table provided in Annex 1 of this paper.

Subsequent paragraphs to Table 2 elaborate on potential sectoral impacts and adaptation actions by UK actors. It should be emphasised that Section 2 does not attempt to rank impacts according to (projected) severity. Thus, whilst the sectoral coverage given indicates from what sources a number of potentially important impacts to the UK may derive from, the order of that coverage should not be interpreted as a ranking. Such a task is beyond the scope of this paper. Similarly, the volume of coverage per sector reflects more the extent of available evidence than the relative importance of the sectoral impacts described. Indeed, in some instances such as ecosystems and water resources, lack of coverage implicitly indicates the need for further research.

Table 2. Overview of International Climate Change Impacts and Effects on the UK

Climatic variable(s) leading to climate impact	**Potential Sectoral Climatic Impact(s) Identified**	**Potential Adaptation Actions by UK**	**Cross-Sectoral linkages**	**Key Uncertainties**
		Agriculture and forestry		
Higher global mean temperatures	Permanent changes in global crop production patterns leading to: a) changes in UK trading patterns with primary product suppliers; b) higher food prices faced by UK consumers	Autonomous responses by UK consumers in response to changes in food prices; Trade negotiation positions influenced by changing food supply conditions	Water resources; Ecosystem services	Pattern of climatic change (extent and timing) and impacts interaction with socio-economic change e.g. technological changes in production
Extreme weather events: precipitation or temperature	Temporary changes in food output for domestic population leading to food poverty and associated population movements and/or conflict. Migration pressures and security concerns for UK	Targeting of current and future international development support to most vulnerable food producing areas and in production practices & technologies most suited to projected regional climatic changes	Water resources; Ecosystem services.	As previous.
		Fisheries		
Higher global mean temperatures	Permanent changes in global patterns of fish stocks leading to changing relative prices of fish in UK	Regional economic diversification strategies for ports etc reliant on fishing.	Tourism; General economic development.	Impacts may be dominated by fish resource pressure, and attendant regulatory regimes, not associated with climate change
		Energy		
Extreme weather events:	Damage or disruption to energy infrastructures and their operation	Energy security diversification strategies in line with wider energy	General economic development.	Technological change and geo-political

precipitation, wind or temperature; storm surge.	internationally that prevent energy transmission to UK. Damage to energy infrastructure assets owned by UK companies.	security policies, including supply of domestic renewables. Encouragement and adoption of defensive measures to protect critical infrastructures.		changes may over-ride climate considerations.
Transport Infrastructure				
Extreme weather events: precipitation, wind or temperature; storm surge.	Damage or disruption to transport infrastructures and their operation internationally that impact adversely on product supply chains to UK or to UK-owned businesses operating abroad.	New infrastructure to be built in less vulnerable locations. Relocation and adjustment of UK business operations. Encouragement and adoption of defensive measures to protect critical infrastructures.	General economic development.	Socio-economic change, including shifting patterns of consumer demand, may over-ride climate considerations.
Tourism				
Higher global mean temperatures	Changes in regional and global patterns of tourist movements intra-annually.	Tourism-related infrastructure including transport and water resources to be provided in areas of growing tourist numbers. Economic diversification strategies in areas currently reliant on tourism.	General economic development.	Socio-economic change, including changes in income levels may dominate climatic factors.
Industry				
Higher global mean temperatures; changes in precipitation	For UK-owned industry: Adverse impacts on labour force productivity in hot weather. Availability & quality of raw materials for manufacturing may decline	Relocation or adjustment of industrial operations e.g. changes in working practices, product design etc.;	General economic development.	Pattern of climatic change (extent and timing) uncertain so difficult to plan. Consumer demand patterns dominate.
Extreme weather events: precipitation, wind or	Damage or disruption to industrial infrastructures and their operation internationally that impact adversely on product supply	New infrastructure built in less vulnerable locations. Relocation / adjustment of UK business operations. Encouragement and adoption of	General economic development.	Socio-economic change, including shifting patterns of consumer demand,

temperature; storm surge.	chains to UK or to UK-owned businesses operating abroad.	defensive measures to protect infrastructures. Demand for UK services.		may over-ride climate considerations.
Financial Services				
Higher global mean temperatures; changes in precipitation	Adverse impacts on financial services sector are indirect and are determined by the extent that physical assets and business operations overseas are effectively owned by banks through their lending policy to UK-owned companies.	Adapting lending policies to reflect changing patterns of exposure in international business operations.	Construction; Planning; General economic development.	Pattern of climatic change (extent and timing) uncertain so difficult to plan.
Extreme weather events: precipitation, wind or temperature; storm surge.	Adverse impacts on financial services sector are indirect and are determined by the extent that physical assets and business operations overseas are given insurance coverage.	Adapting insurance coverage policies to reduce projected international exposure.	Construction; Planning; General economic development.	Pattern of climatic change (extent and timing) uncertain so difficult to plan.
Health				
Higher global mean temperatures; changes in precipitation	Decline in agricultural productivity and/or supply of water resources may lead to fall in public health in some regions leading to increased need for international development assistance.	Increase in ODA, targeted at regions most vulnerable to adverse climate change impacts.	Water resources; General economic development.	Pattern of climatic change (extent and timing) uncertain so difficult to plan, exacerbated by uncertainties in socio-economic change.
Extreme weather events: precipitation,	Extreme events may lead to malnutrition, starvation, and associated need for emergency aid.	Increase in ODA, targeted at regions most vulnerable to adverse climate change impacts.	Agriculture; General economic development.	Pattern of climatic change (extent and timing) uncertain so

wind or temperature; storm surge.				difficult to plan, exacerbated by uncertainties in socio-economic change.
Ecosystem Services				
Higher global mean temperatures; changes in precipitation	Provisioning services of ecosystems e.g. as supplier of raw materials and waste management processes overseas may decline and affect UK-owned business operating in these areas or that make use of such resources. Support functions may deteriorate leading to migration or resource conflict and associated impacts on UK.	Support for international conservation treaties; international development assistance that supports diversification away from extensive or intensive use of ecosystem resources.	Water resources; General economic development.	Socio-economic change, including population growth and technological change, may result in increased demand for ecosystem services that dominate climate factors.
Water resources				
Higher global mean temperatures; changes in precipitation	Declines in water availability lead to changes in a number of sectors, as indicated in other parts of the table, and including many aspects of human livelihood.	Increase in ODA, targeted at regions most vulnerable to adverse climate change impacts. Support for water efficient and storage technologies.	Ecosystem services; General economic development.	Socio-economic change, including population growth and technological change, likely to exacerbate climate factors.
Sea-Level Rise				
Higher global mean temperatures; storm surges	Sea-water inundation may lead to loss of land and associated socio-economic activity, with pressures to relocate/migrate away from coast. Associated impacts on UK.	Coastal management strategies including hard and soft defences and accommodation.	General economic development.	Socio-economic change, including population growth, likely to exacerbate climate factors.

Agriculture[4]

Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C, depending on the crop, before decreasing in some regions with more sizeable temperature increases. At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), increasing the risk of hunger in these regions. Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this threshold production is projected to decrease. Moreover, increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes.

These broadly identified projected changes, coupled with the considerable uncertainties remaining in the projections of future climate change, and socio-economic factors affecting demand and supply such as demographic change, dietary habits, diffusion of agricultural production technologies, demand for energy, including bio-fuels, which may compete with food production for a limited land supply, etc., make secondary effects on the UK difficult to identify. However, there is a general expectation that world food prices will tend to rise in response to a significantly warmer climate (see e.g. Parry et al., 2004, who suggest price increases of 2-6%). Indeed, under some scenarios and models, there could be significant declines in agricultural productivity in many world regions. As a consequence, raw material inputs and final food prices may rise for UK producers and consumers.

In addition to possible changes in the prices of imported agricultural products, significant increases in fluctuations in food productivity may be expected to exacerbate concerns over food security and risks of food shortage, and their associated famine risks. In these cases, humanitarian aid from more developed countries such as the UK may be required. The IPCC (Parry et al. 2007) predicts that climate change will marginally increase the global number of people at risk of hunger, compared with overall large reductions due to projected future socio-economic development.

It is clear that, as with subsequent sectoral impacts outlined below, adaptation may take many forms and be operational at a range of decision-making levels. For example, whilst food security concerns may encourage countries to adjust their positions in WTO discussions at an international level as they seek greater control over their agricultural markets and exports, at a national level governments may increase incentives to farm new areas, and/or to increase farming intensity. At a farm level, the farm response may be the choice of crop, based on changing prices and/or yield changes likely under a changing climate. UK adaptation action is likely to be autonomous consumer behaviour, based on responding to market price changes, or UK agricultural producers who are also responding to changing market conditions.

[4] Note that the key parts of this assessment are also applicable to the global forestry sector.

Fisheries

The future impacts of climate change are expected to result in a number of changes to marine species and to fisheries. Climate change is an additional pressure on fish stocks whose resilience is low, because of the impact of fishing activities and, to a lesser extent, pollution or physical destruction of habitats. The changes from climate are therefore likely to increase the vulnerability of fisheries.

The impacts of climate change are already being observed in European Seas (Halpern et al., 2008). These changes have important consequences for the way organisms within an ecosystem interact and ultimately for the structure of marine food-webs at all trophic levels, including fisheries. In addition, many species of fish and plankton have shifted their distributions northward, and sub-tropical species are occurring with increasing frequency in European waters whilst sub-arctic species are moving northwards. As examples: there has been a major northward movement of warmer water plankton in the north-east Atlantic (1100 km over the past 40 years) and a similar retreat of colder water plankton to the north (EEA/JRC/WHO, 2008) and this will have an impact on distribution of fish in that region; rate of north-ward movement of a particular species, the sailfin dory, has been estimated at about 50 km/year (high confidence).

Such changes affect the composition of local and regional marine ecosystems. They also have socio-economic effects; the three large species that have decreased their range the most in the North Sea are all commercially relevant species, while only one of the five most increasing species that have increased their range, and less than half of the all the species that expanded their range, are of commercial value. A climate change induced shift from large to smaller species is thus likely to reduce the value of North Sea fisheries (Hiddink and Hofstede, 2008).

These observed changes in distribution, and the ones that are likely to occur with future climate change do not necessarily reduce the overall fishery potential for the UK fleet, but might lead to changes by region, or changes in the commercial value by region. This has potential for UK waters, but also wider effects on the UK fleet. At the same time, the potential for new fishing opportunities may open up e.g. in the Arctic regions, where – with the reduction in sea-ice - boats will have increased access.

In addition, the kinds of fish that are available for human consumption are not necessarily affected by the observed and projected distribution changes, because fish are often transported long distances from where they are caught to markets. However, fish prices may increase if certain species decline, and there are likely to be changes in the variety of locally caught fish.

The projected changes in the location and availability of fish stocks will have strong economic impacts, as well as localised employment and social consequences, in coastal areas where fishing activities constitute the most important source of revenue. The changes in distribution may also affect the management of fisheries and have implications for allocations of quotas. Adaptation in the UK is therefore likely to be primarily focussed on improving these management arrangements such that sustainable fish populations can be maintained. Economic diversification in

potentially affected local communities is also likely to be necessary under climate change scenarios. In both cases, these adaptation responses are simply extensions of actions currently being undertaken as a response to the risks of over-fishing.

Energy

The UK's current energy mix is heavily reliant upon gas, oil and coal, all of which are dependent to a greater or lesser extent on imports from elsewhere in the world, and all of which are therefore at least potentially at risk from climate changes occurring outside the UK. Specifically, the UK imports five main types of energy/resources.

1. Crude oil or refined from various countries
2. Natural gas and Liquefied Natural Gas (LNG)
3. Electricity via a grid connection to France.
4. Coal (imported from Russia, Australia and South Africa)
5. Uranium for nuclear power generation

An idea of future exposure is given by Ofgem (2008) in its Long term Electricity Network Scenarios (LENS) report[5]. The study presented 5 different scenarios of future grid/energy composition. Under these scenarios, renewables increase to about 30% of electricity production in 2050, nuclear and fossil fuels including Carbon Capture and Storage (CCS) decrease slightly. Oil use is likely to decrease although this is also dependent on changes in the transport sector. Whilst there is considerable uncertainty in the projections, the common theme is that fossil fuels are likely to decrease slightly but still make up a significant proportion of the UK's energy mix, so that it remains important to consider the long term impacts of climate change upon these import flows.

Oil and gas are both primarily imported via pipelines to the UK, which represent a low risk option in terms of climate change. However, it is likely that the UK will need to increase its imports from other countries in the future. The most significant potential climate risks to the UK's energy dependencies are likely to be:

1. Transportation risks to shipping and ports. Transportation applies to all fuels and resources being imported. The disruption to the international oil market of the impact of Hurricane Katrina is an example of a risk that may increase under climate change futures.
2. Coastal infrastructure, the direct risks such as sea level rise and intense storms associated with climate change present a risk to this infrastructure which is predominately in coastal locations.
3. Indirect risk associated with climate change influencing energy demand in other areas of the world which has knock on political and or cost implications for the UK
4. Climate change influencing the operational capability of traditional power plants such as nuclear power which would influence the amount of energy that could be imported from neighboring countries such as France. The heat wave of 2003 caused problems to electricity production as river temperatures rose.

5 http://www.ofgem.gov.uk/Networks/Trans/ElecTransPolicy/lens/Documents1/20081107Final%20Report.pdf

This meant that the cooling efficiency of conventional and nuclear power stations was reduced and six power plants had to be shut down[6].

5. Arctic pipelines transporting oil and gas. Increasing temperatures are already causing problems to artic infrastructure built on permafrost[7], this will only get worse in the future presenting a hazard to the operation of these pipelines.

There appear to be very few studies that are looking at how to reduce climate risk in the energy sector. One noticeable exception is a briefing paper by Chatham House entitled 'the vulnerability of energy infrastructure to environmental change'. One issue raised here is that due to societal and environmental opposition when energy infrastructure is renewed it tends to be in the same location as before. For example new power plants tend to be located on the same site and a re-evaluation of climate conditions and predictions is not generally a major consideration.

It is worth considering that the global energy market is extremely interconnected in terms of prices so that if production is damaged elsewhere in the world this will have large implications to the price of fuel and energy.

Under current mitigation commitments, the UK will need to take steps to decarbonise its transport sector. Biofuels represent an opportunity to move a low carbon society through reducing dependence upon oil imports to the UK. Since current UK policy has recently revised down UK biofuel targets, the UK will probably need to import at least a third of its biofuel in the future. This proportion is influenced by what approach is taken towards the domestic bio-energy resource and whether this is used to generate heat/electricity. The climate change impacts upon biofuels are likely to be similar to the agricultural sector and the transportation of fossil fuels.

The IPCC states that industry is quite well placed to adapt to climate change. The energy sector is likely to have the technological and economic resources to recover from extreme events and adapt over the longer term to gradual changes[4] It is likely that adaptation action by the UK will focus on developing alternative energy supply sources as well as requiring that infrastructure operation and management specifications are matched adequately to potential climate risks. The former action accords with current government policy towards energy security.

Transport Infrastructure

Similar to those highlighted in the energy sector, the risk of damage to transport infrastructure from climate change arises from potential changes in the frequency and/or intensity of extreme events. Disruption to the infrastructure of all modes of transport is potentially likely as a result of these events. The resulting impacts to the UK derive either from the disruption of product supply chains or personnel movements relating directly or indirectly to the operations of UK-owned businesses, and/or on UK consumers. For example, port infrastructures are likely to be vulnerable to climate change impacts resulting from sea level rise and subsidence in some

[6] IPCC 4th Assessment Report, Chapter 7.
[7] http://www.chathamhouse.org.uk/files/13901_bp0409energy.pdf

regions and a greater frequency of violent storms and flooding, and these impacts may directly affect shipment of goods to be imported to, or exported from, the UK.

Socio-economic change will influence the degree to which climate change impacts are important. In the example of port infrastructures, a projected continuing growth in global cargo volume may also make it more difficult for port authorities (and public authorities in general) to take the necessary adaptation measures and result in possible mal-adaptation e.g. by extension of ports over greater areas to the detriment of natural areas.

Tourism

Mass summer tourism is closely associated with climate, in terms of the source of tourists and their preferred destination. At present, the predominant (summer) tourist flows are from the UK to the Mediterranean coastal zone. This region is the world's most popular holiday region: it attracts some 120 million visitors from Northern Europe each year, the largest international flow of tourists on the globe and their spending is in excess of 100 billion Euros (EEA/JRC/WHO, 2008). Coastal tourism is also vulnerable to climate change.

With growing income and increasing leisure time, the tourism industry in Europe is expected to continue to grow. However, temperature rise is likely to change summer destination preferences in Europe, with strong distributional effects. Seasonality is a key issue in tourism, and the summer months are the dominant period for the Mediterranean region and Europe as a whole. The effect of climate change is likely to make outdoor activities in northern Europe including the UK more attractive, while summer temperatures and heat waves in the Mediterranean, potentially exacerbated by limited water availability, may lead to a redistribution or a seasonal shift in tourism away from the current summer peak, either to a bi-modal distribution either side of the summer peak, or a transfer to other more northerly regions of Europe, which become more attractive, as shown in modelling work within the PESETA project. The potential shift in the major flows of tourism within the EU will be important in regions such as some Mediterranean regions, where tourism is a dominant economic sector, though autonomous adaptation responses will be critical.

Analysis in Metroeconomica, (2006), models the tourism flows in Europe with and without climate change to 2100. Some results are presented in Table 3. For all the countries listed here, and all climate and socio-economic scenarios, the number of inbound tourists increases. Population growth and economic growth in the rest of the world cause the shift in the balance. The impact of climate change is either to increase the rate of growth – for example, the UK– or to decrease the rate of growth – for example, Spain and Italy. The analysis also shows changes in country-specific patterns. For example in the UK, climate change amplifies the shift towards more inbound tourists relative to outbound. This is because the UK becomes more attractive for UK citizens and so holidays abroad are replaced by domestic holidays; in addition, the UK becomes more attractive for tourists from abroad. By the 2050s, for all of the climate change scenarios, there are more tourists arriving from abroad than there are tourists leaving the UK.

Table 3. In-bound tourists - selection of European countries for the High scenarios, with and without climate change for the time slices 2020s, 2050s and 2080s (Millions)

	With climate change			Without climate change			Difference		
Inbound tourists	**2020s**	**2050s**	**2080s**	**2020s**	**2050s**	**2080s**	**2020s**	**2050s**	**2080s**
Czech Rep.	46.2	126	213.6	50.7	124.6	194	-4.5	1.3	19.5
Denmark	2.2	3.3	4.7	2.4	3.3	4.4	-0.2	0	0.4
France	77.3	109.4	152.5	89	122.5	167	-11.7	-13.1	-14.5
Germany	20	32	47.5	22.5	32.2	43.5	-2.5	-0.2	4
Greece	13.2	18.3	24	15.9	23.2	32	-2.7	-4.9	-8
Ireland	6	8.4	12.1	6.9	9.2	12.4	-0.9	-0.8	-0.4
Italy	39.8	55.7	75.7	47.3	67.3	92.8	-7.4	-11.6	-17.1
Netherlands	8.5	12.1	17.3	9.7	13.1	17.7	-1.2	-1	-0.4
Spain	48.4	66.6	91.4	57.9	81	113	-9.5	-14.4	-21.5
Sweden	3.5	6.2	10.3	3.5	4.8	6.3	0.1	1.4	4
UK	42	87.9	175.9	45.6	88.5	162.8	-3.6	-0.6	13.1

A projected increase in the number of visitors to the UK as a result of climate change in the UK and elsewhere, combined, has potential positive effects on the operations of tourism-related businesses in the UK, in terms of increased revenues. There may, however, be associated pressures on e.g. infrastructure provision and water resources in UK regions such as SW and SE England, Wales and Scotland. Adaptation action is therefore likely to be in the strategic planning within potentially affected regions of how to cope with increased visitor numbers.

Industry

Disruption to industry and business operations undertaken in other countries but owned by UK citizens, of the sort outlined in the discussions of energy and transport infrastructures above, can be generalised. It is possible that the most vulnerable business operations will be those undertaken in countries with least adaptive capacity and highest vulnerability, for example, the former Commonwealth countries in East Africa and South Asia.

For UK services and industry in general, there may also be a positive dimension of international climate change impacts: the need for expertise and technologies to support adaptation measures throughout the world may create many opportunities for UK companies to develop outside Europe, supplying export or transfer technologies and know-how. This is particularly likely to be the case in the water sector (urban water supply including development of desalination, technologies for water saving and re-use), the energy sector, construction (design and engineering activities), financial services and insurance.

Financial Services

Two elements of the financial sector in the UK are thought to be particularly vulnerable to climate change impacts projected internationally. First, the insurance and re-insurance is exposed to the projected increase in frequency of extreme weather events globally to the extent that it provides cover to health and property that is vulnerable to such events and whose cost is not internalised in the premiums asked for such cover. Extreme events such as Hurricanes Mitch and Katrina are illustrations of the types of risk that may need to be covered.

Second, the banking and insurance sectors are exposed to the extent that they hold physical assets that may be vulnerable to changing climate – either through extreme events or through changes in mean values. For example, a bank lending to a company that owns a port in a country whose coastal geography makes it particularly susceptible to sea level rise and associated storm surges will have a liability that grows in size over time. Again, the financial sector exposure will be determined by the extent to which the increased risk is captured within the contract agreed between the parties.

The risks to the financial services sector are explored in more detail in Section 3, below.

Health

Climate change-related exposures are projected to affect the health status of a large number of people, particularly those with low adaptive capacity. For these groups, this includes potential effects from increases in malnutrition and consequent disorders from changes in agricultural productivity, increased deaths, disease and injury due to heat-waves, floods, storms, fires and droughts, the increased burden of diarrhoeal disease from reduced water availability or quality, and the altered spatial distribution of some infectious disease vectors from mean temperature changes. Studies in temperate areas project some benefits (e.g. fewer deaths from cold exposure), but overall it is expected that these benefits will be outweighed by the negative health effects of rising temperatures worldwide, especially in developing countries.

Expected changes in the range and transmission potential of malaria, e.g. in Africa, remain uncertain. In the UK, localised outbreaks are possible in areas, even in cases where the disease has been eradicated, but vectors are still present. However, a major factor here will be the external dimension, either from risk from the UK population travelling in endemic areas, or through migration. In the case of vector-borne disease, provision of prior inoculation and border control surveillance are two primary adaptation options that may be increasingly required.

Ecosystem Services

The resilience of many ecosystems is likely to be exceeded this century by a combination of climate change, other disturbances, and other global change drivers (e.g., land-use change, over-exploitation). Changes to ecosystems are predicted to

have predominantly negative consequences for biodiversity, and ecosystem goods and services. Approximately 20-30% of plant and animal species are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C. Increases above this are expected to lead to major changes in ecosystems structure and function. The potential shift in climatic zones and potential distribution of UK species might lead to some (where migration is possible, such as bird species) moving to areas outside the UK. The demand for ecosystem services within the UK (e.g. provisioning services) will also affect pressures on biodiversity-ecosystems outside the UK.

A summary of the ways in which ecosystem services provide welfare value to humans is presented in Table 4. It serves to emphasise that ecosystems have a range of different functions in affecting human welfare. Within a global perspective it can be understood that such changes have a variety of potential impacts on the UK including, for example, changes in the quality and availability of ecosystem services as raw material inputs or waste management service provision to UK-owned business operations overseas. These impacts may therefore affect the location or viability of some operations which would have to adapt to survive. In addition, for ecosystem-based tourism, the opportunities open to UK travellers may become constrained.

Table 4. International Ecosystems and Welfare Value to UK - Taxonomy

Economic value interpretation	Biodiversity & Ecosystem benefits
Genetic and species diversity	Inputs to production processes (e.g. pharmaceutical and agriculture industries) owned by UK.
Natural areas and landscape diversity	Provision of natural habitat (e.g. protection of wilderness areas and recreational areas) and associated tourism and amenity values.
Ecosystem functions and ecological services flows	Ecological values (e.g. flood control, nutrient removal, toxic retention and biodiversity maintenance), and associated values for e.g. supply chain operations.
Nonuse of biodiversity	Existence or moral value (e.g. guarantee that a particular species is kept free from extinction) For all UK citizens.

Given the breadth of ways in which global ecosystems have welfare implications for UK businesses and citizens it is difficult to further differentiate these impacts on a geographical basis. However, research subsequent to this scoping study would be usefully orientated towards such a task, and a quantification of these impacts.

Water

By mid-century, water availability is projected to decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water-stressed areas. Drought-affected areas are likely to increase (in extent). Heavy precipitation events are very likely to increase in frequency, increasing flood risk. The potential impacts on the UK are therefore similar to those associated with transport

infrastructure vulnerability, discussed above, as well as those associated with ecosystem services, to which water resources are closely linked.

Sea level rise

Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s, under IPCC scenarios (Nicholls and Lowe, 2004). Those densely-populated and low-lying areas where adaptive capacity is relatively low, and which already face other challenges such as tropical storms or local coastal subsidence, are especially at risk. The numbers affected will be largest in the mega-deltas of Asia and Africa (e.g. potentially in excess of 1 million people potentially displaced by sea level trends (Parry et. al., 2007) in the Nile delta, the Ganges /Brahmaputra delta and the Mekong delta by 2050), while small islands are especially vulnerable.

The risks are likely to increase most in developing countries and by 2070, 9 of the top 10 cities exposed to coastal flooding in terms of population exposure are in Asian developing countries. In countries where development levels remain lower, increases in disasters and humanitarian crises will lead to increased pressure on the resources of donor countries, including capacities for emergency relief operations.

Concluding comments to Section 2

Table 2 and the sub-sections that follow provide a first indication of the range of climate change impacts projected to occur internationally, and that may have subsequent effects on UK citizens, its government or its businesses. It is clear that the nature of these impacts is indirect and should therefore generally be couched in greater uncertainty than direct climate change impacts in the UK. The uncertainty attached to the nature and dimensions of these impacts also limits the extent to which their distributional consequences are described. Future research efforts would therefore be usefully focussed on quantifying the identified impacts – using scenario analysis – to explore these dimensions.

Section 3. Further Assessment of Aspects of International impacts of climate change on the UK

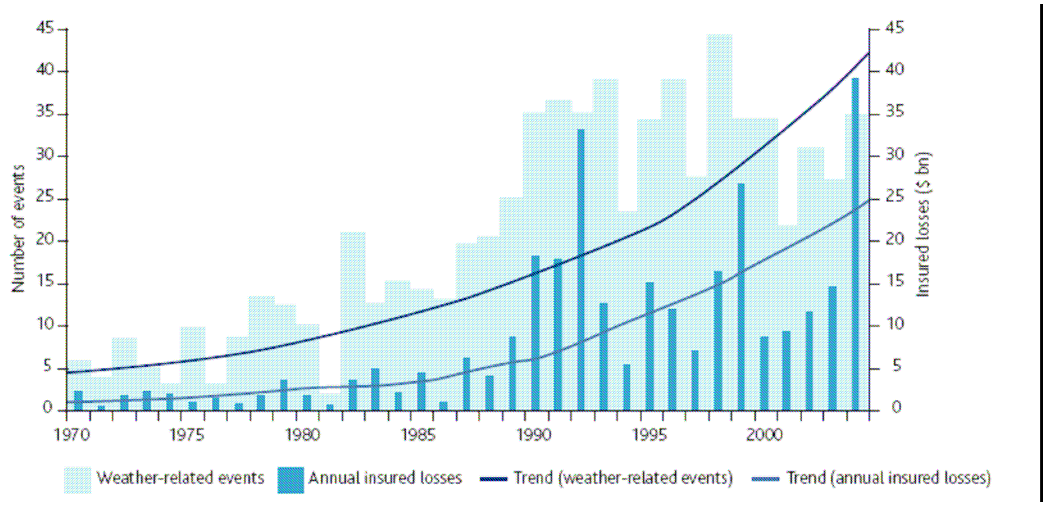
In this sub-section, we review in further detail a number of specific impact types identified in Section 2. These include those impacts associated with price changes in the agricultural and financial markets, reflecting the UK economy's relatively high dependence on imported foodstuffs and strength in the global financial services sector, respectively. As a consequence, these two sectors are thought – by this research team at least – as being particularly vulnerable to international dimensions of climate change and thus worthy of particular attention. We also discuss two responses – conflict and migration – to international climate change impacts in the countries directly impacted that may have consequences for wider strategic and international development activities undertaken by the UK, as well as the diaspora in the UK from these directly impacted countries.

The financial sector

Introduction

History has shown that society in general, and insurers in particular, are often caught unprepared for ostensibly "inconceivable" disasters. This reflects, in part, the recurring social miscalculation of using the past to predict the future while under-investing in disaster preparedness. Figure 1 shows that the impact that weather events are exerting over the insurance sector is increasing. Global weather-related insurance losses from large events have escalated from a negligible level in the 1950s to an average of US$9.2 billion yr-1 in the 1990s. The weather-related share of total losses is as high as 100% in Africa and 98% in Europe (reported in IPCC 2001). Indeed Mills (2005) reported that insurance payouts for weather-related disasters in the developing world were three times the amount provided by international aid. Insurance is a major global industry. Not only do people invest in insurance companies; every company people invest requires insurance to run its business. The impact of climate change on the insurance sector could therefore have a ripple effect throughout the economy.

Figure 1 - Global costs of extreme weather



Source: ABI 2006

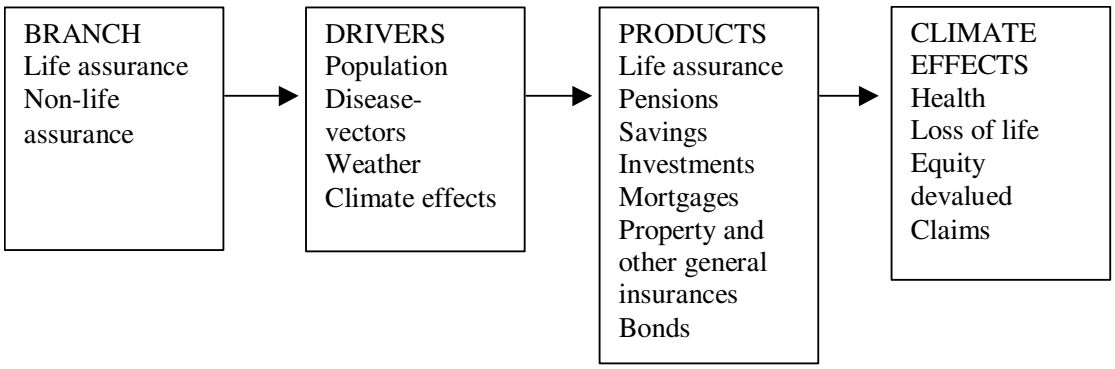
The UK, and the financial markets in London, particularly, have a distinct exposure to these climate-related risks. London is one of the three largest financial centres in the world (alongside New York and Tokyo) and has the largest share of trading in many financial markets, including foreign exchange of which it controls 36% of the global turnover. The City of London has a GDP of £22 Billion - equivalent to 2.6% of the UK GDP. The London based insurance industry comprises approximately 90% of the total UK employment in the industry, (about 300,000), contributing 1.4% of UK GDP, and the UK Insurance market is the third-largest in the world, contributing around £8 billion a year to UK overseas earnings, reflecting a broad exposure in global economic activities. The UK insurance industry in 2000 held £796.5 billion worth of assets globally.

The UKCIP Scoping Study for the South East of London (Wade et. al. 2001) describes in general terms how the UK based insurance industry is likely to be impacted by climate change in the UK. The study notes that since "many activities within the insurance sector are weather sensitive, the industry has developed wide

experience and understanding of how weather conditions impact on its operations. These include claims associated with severe short term events including rain and windstorms, freezing weather and longer term events such as hot, dry spells the latter increasing building susceptibility to subsidence".

Dlugolecki, in CII (2001) generalises the interaction between insurance and climate change in the way illustrated in Figure 2 below. The diagram shows that the core activities of insurance companies are likely to be impacted by climate change either by changes in risk transfer arrangements, changing vulnerabilities of financial and non-financial assets held, and wider economic changes.

Figure 2: Life and non-life insurance activities and climate change



The threat to the sector in the UK is exacerbated significantly by the high level of inter-dependence that exists in global capital and insurance markets. IPCC (2001) notes as a measure of insurance vulnerability the ratio of global property/casualty insurance premiums to weather-related losses fell by a factor of three between 1985 and 1999. The IPCC synthesis concludes that "there is high confidence that climate change and anticipated changes in weather-related events that are perceived to be linked to climate change would increase actuarial uncertainty in risk assessment and thus in the functioning of insurance markets". As one Insurance sector representative has commented, "insurance has historically been about predicting the unpredictable. Climate change means that predicting the unpredictable itself becomes unpredictable", (Wade et. al. 2001). The following paragraphs outline the mechanisms through which the UK financial sector may be impacted by global climate change.

Climate change presents some **opportunities** for the financial sector in the UK. The sector in the UK provides services to the global economy. The prospect of increased risks and structural changes should allow the sector to grow in response. For example, the insurance and reinsurance industry has a significant presence in UK and the increased risk associated with climate change globally would likely lead to a general expansion of the sector. Furthermore, London represents a strong candidate for becoming the centre of a number of new emerging climate change mitigation and adaptation markets such as carbon trading and the overseeing of mitigation and adaptation finance. It is possible to envisage that such opportunities might combine to allow London to further develop as the lead global financial centre specialising in assessing and mitigating climate change risks within the financial sector. However,

global climate change also poses a threat to the UK financial sector; both directly via exposure to risk as well as any shrinkage in the global economy. These threats include:

1. **The UK's foreign investment portfolio suffers due to the impacts of climate change**. UK businesses have interest and assets in a number of regions and markets. For example, UK corporations may have particular investments in certain regions or sectors, such as offshore oil and gas. A further issue might arise with UK manufacturing 'offshoring' much of their product chains and allowing them to become increasingly complex[8] and global in nature. It is likely that such a system will posses both vulnerabilities and resilience, due to its complex and dispersed nature.

2. **The risk that catastrophic event(s) lead to significant losses in the insurance underwriting system.** In the first instance this would impact on those exposed as underwriters. To the degree that the liability resides within the UK, the resulting economic impact would affect the wider economic prosperity of the UK as a whole. In addition, the loss of confidence which would result from any breakdown in the system might lead to migration of the sector from the UK. In theory at least, existing risk assessment systems are designed to spread associated risks and therefore ensure that losses are covered in most eventualities. However, such systems are based on historical observed occurrences and therefore might struggle to quantify the additional future risk posed by climate change. A more serious threat comes from the failure of the sector to understand new patterns of correlation resulting from complex changes in systems brought on by climate change. An example would include damage caused by the breakdown in the rule of law - resulting from inequities brought on by climate change-induced natural disasters - leading to the loss of major mineral production capacity.

3. **Certain activities face significant increases in insurance premiums or become uninsurable – i.e. an 'insurance crunch'**. Significant changes in assessed risk would lead to significant increases in premiums in future years. This would represent a direct threat to economic sectors reliant on insurance for their operation or development but also to the global economy as a whole. It is possible that the outfall in the insurance sector resulting from a significant event could lead an 'insurance crunch', similar to the credit crunch seen in credit markets in 2008. A significant difference would come from the more limited feed-back in the system, unlike in the credit sector where the economic downturn brought on by credit restrictions further contributed to toxicity of mortgage backed-assets. However, the additional economic burden placed on the global economy as a whole due to increased insurance premiums might lead to an economic dampening similar to the response in the credit crunch.

To better understand the potential magnitude and likelihood of these events occurring, it is necessary to develop and simplified model of the financial sector which explores

[8] To illustrate, a UK company might oversee the shipping of several raw materials to a manufacturing country before it is shipped to a number of final markets where the profit is made.

the management of risk and key relationships under steady state conditions, and under significantly increased pressure brought on by climate change. Such a model is proposed in
Figure **3** below.

Figure 3 - The management of risk by the financial sectors within normal operating conditions

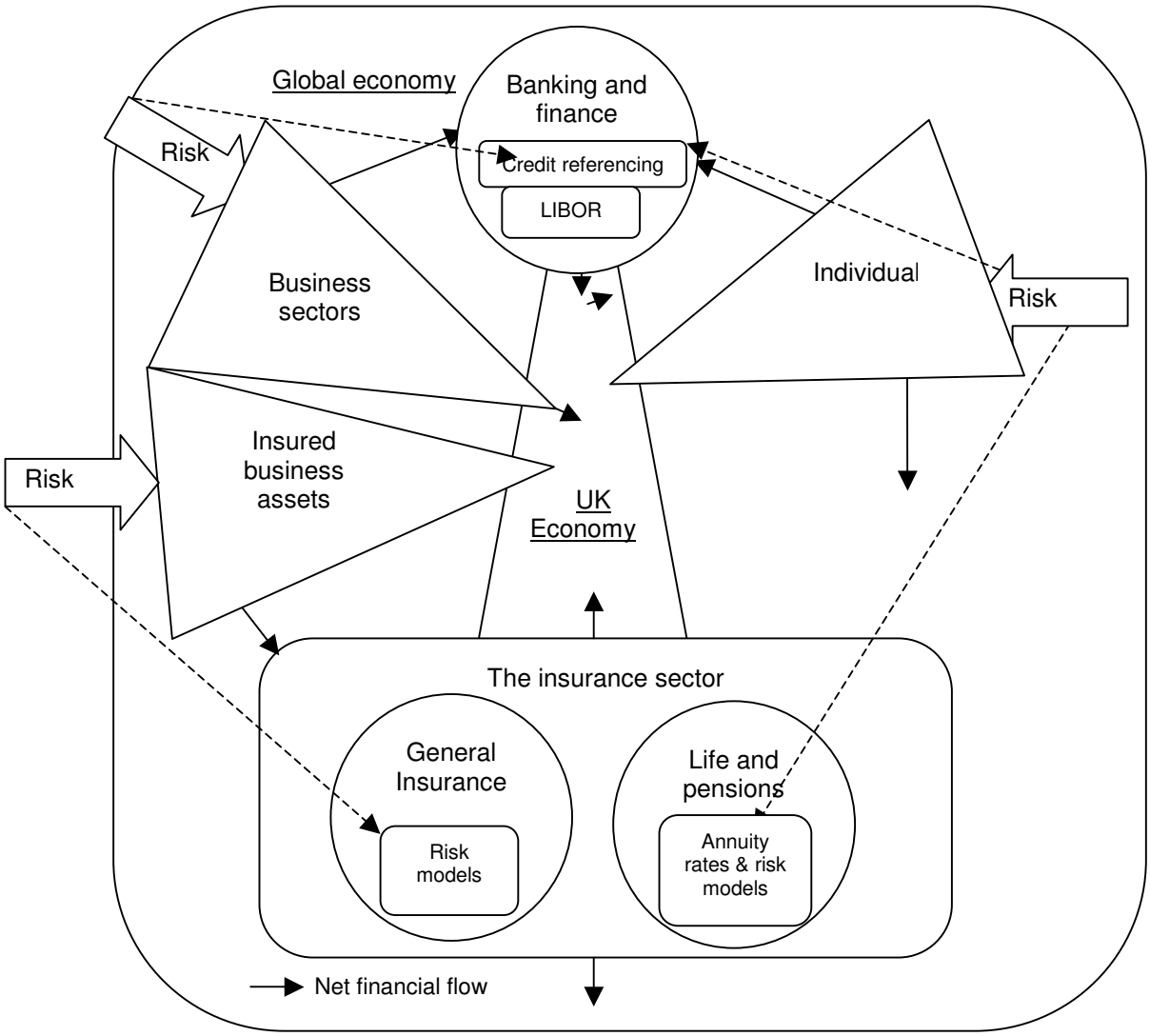


Figure **3** above shows that, within normal levels of operating risk the financial sector provides the following benefits and costs to the UK economy:

- **C_1**: Businesses and private individuals pay net premiums to the insurance sector to cover the sector's net costs and profits where merited.

- **C_2**: Businesses and private individuals pay net fees to the banking industry insurance sector to reflect the risk of lending.

- **B_1:** Businesses and private individuals benefit from financial services by insuring against extra-ordinary risks and providing investment capital.

- **B_2:** Over time, the insurance and banking sectors receive net incomes from businesses and private individuals for the provision of financial services.

- **B_3:** The UK economy receives net income via taxes and benefits from the prosperity resulting from hosting a large part of the sector.

- **B_4:** To the degree that the UK sector performs better than its rivals, UK shareholders benefit from profits.

Key to the success of any financial sector is the sophistication of its risk models (e.g. credit referencing models, insurance risk models and the models which inform the setting of annuity and the LIBOR (London Inter-Bank Offered Rate) rates). Economic theory suggests that total benefits are greater than the net costs and that over time businesses and private individuals receive an overall economic benefit from the sector whilst the financial sector secures long-term profit. However, at times of change many of these cost and benefits will change and the system as a whole may come under threat. This is explored with reference to the following two scenarios.

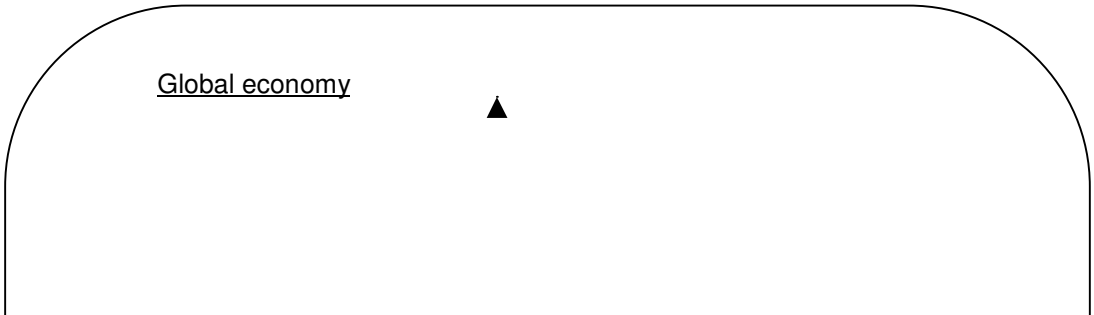
- **Climate change impacts are fully predicted and understood**

Many of the first degree environmental impacts of the climate changing will have already been anticipated and will naturally be factored into the premiums charged by the insurance industry as they become relevant. Furthermore, many climate change impacts will develop overtime, providing the industry ample opportunities to understand the emerging risks and adjust their models accordingly. These risks therefore largely represent normal operating conditions as set out in
Figure **3** and, to the degree that the insurance sector is able to rationally respond, premiums will increase and the size of the sector is likely to increase in response. Under this scenario, all four of the benefits set out above (B_1 to B_4) might be expected to increase as the need for financial services increases. Businesses and private individuals will bear additional insurance costs (i.e. C_1) which would impact on global economic growth. Overall, it is quite possible that the economic benefits to the UK of an enlarged insurance sector would out-weigh the economic implications of the higher costs faced by UK premium payers.

- **Climate change impacts are not fully anticipated**

This scenario leads on from, and is additional to, the outcome of the previous scenario. It is possible that some impacts of climate change, (e.g. increased storm frequencies), will occur not having been anticipated. Furthermore, it is possible that the complex relationship underpinning the secondary implications of climate change, (both environmental and social in nature), will not be fully understood and reflected in insurance premiums. If these unanticipated impacts are significant, payouts will exceed premiums and the net financial flows will reverse as shown in Figure 4.

Figure 4 - The management of risk by the financial sectors within normal operating conditions



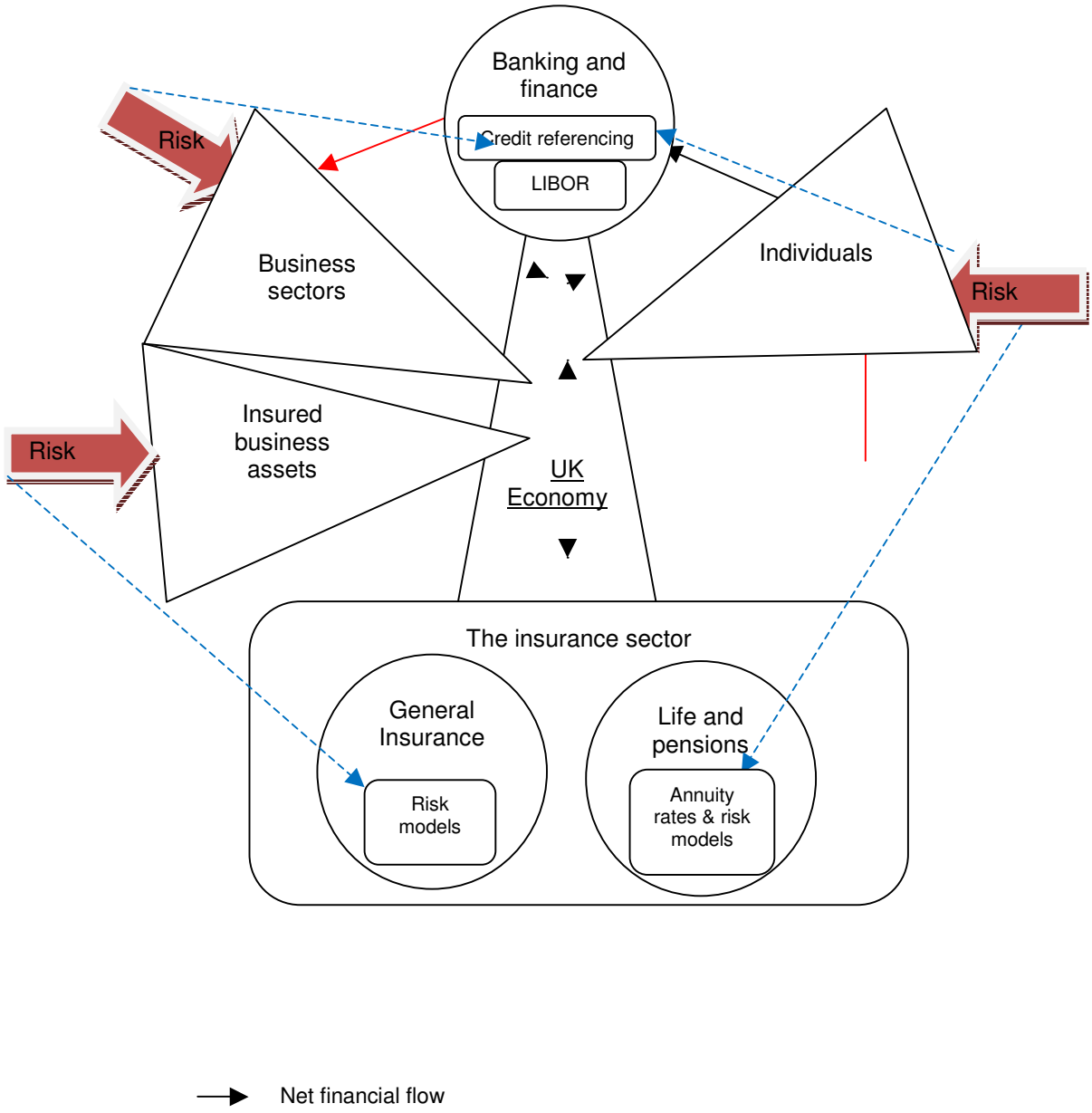


Figure 4 suggests that, in the event of significant and unanticipated climate change impacts, the insurance sector would suffer losses since it is required to make greater than anticipated pay-outs out to their policy holders and may result in the banking sector suffering higher levels of defaults on loans. These effects may be exacerbated by inflation of construction costs following natural disasters and general asset market falls resulting from insurers selling their investments to cover net losses. This would impact on shareholders and insurance underwriters in the first instance, though, ultimately, the prosperity of the UK as a whole could be impacted. If the losses are great, banks or insurance companies may collapse leading to job losses.

Ultimately the insurance system could fail to cover all of their liabilities, leading to an 'insurance breakdown'. In the absence of this effect, businesses and private individuals not directly affected by climate change may not be immediately affected. Over time, however, the charges and premiums are likely to increase, reflecting the greater risk. This process differs for the different sub- financial sectors:

- **The banking sector** would seek to increase the lending rates they charge in order to reflect the increased probability of people defaulting on their loans. Where

loans and mortgages are not immediately recoverable by the banks, (as they have a fixed interest rate component or the loan is associated with an investment), there is a chance that these loans will represent an unknown asset to the bank and would therefore be considered as 'toxic' to the sector as a whole. If the extent of the toxicity is significant, LIBOR would increase whilst the risk is being understood by the sector. Ultimately, a global level feed-back process as seen within the 2008 'credit crunch' might be seen where the lack of capital feeds-back to economic uncertainty and greater defaults on loans.

- **The insurance sector** would seek to increase the premiums they charge their customers to reflect future uncertainty in pay-outs. Unlike the banking sector, this can be done almost[9] entirely within a year of the increased risk being perceived and therefore any toxicity will be short-lived. Where the emergent risks can be fully understood by the sector, the impact would likely be limited to that seen under an *'insurance squeeze'* scenario. However, it is likely that many of the risks will be new and complex, involving subtle social interactions in some cases. Where this is the case and uncertainty is great the sector is likely to take a cautious approach to setting their premiums, potentially leading to an *'insurance crunch'*, where sections of those previously insured are either refused cover or face very considerable increases in premiums. This would cause not only hardship and undesired exposure to risk for those concerned, but also could also cause certain climate-sensitive activities to cease.

Recent history has shown that weather-related losses can stress insurance firms to elevate their premiums, withdraw coverage or lead to insolvency. Indeed, the stresses exerted on the sector as a whole as a result of recent pay-outs have caused changes in the reinsurance system which has further reduced system reliance. For natural catastrophes, reinsurance normally takes the form of an "excess" contract; primary insurers retain the first tier of losses up to a "trigger point" above which they purchase reinsurance, which operates up to a specified "exit point" or upper limit. After the catastrophes of the last two decades of the 20th century, reinsurers are leaving more of the risks with primary insurers, by increasing trigger points and lowering exit points. This removes resilience from the sector as a whole and leaves the sector more venerable to failure.

Severe events can also threaten reinsurers. Indeed, several became insolvent or were absorbed by larger firms during the crisis period of 1989-1993. The unexpectedly costly European windstorms of 1999 caused further problems. For example, an already weakened Australian reinsurer covering these storms became insolvent despite total assets of US$2.3 billion (reported in IPCC 2001). According to the Insurance Information Institute, the world's catastrophe reinsurance industry lacks the capacity to insure mega-losses in excess of US$50 billion. Government reinsurance systems have also shown signs of stress as illustrated by the casa in France where reserves fell by 50% during the 1990s and reinsurance rates rose sharply (reported in IPCC 2001).

[9] The most notable exception to this is some life insurance policies

The 2005 hurricane season in the USA was the most active ever and resulted in record insured losses. The year's three most devastating hurricanes—Katrina, Rita and Wilma—resulted in at least $45.2[10] billion in insured property losses. In the case of Katrina, much of the damage was the result of flooding, rather than wind, prompting key coverage questions. The sheer magnitude of the damage caused by Katrina-related events has led to difficulty in determining the cause of building destruction and multiple lawsuits. Flood cover was not included in the home insurance policies of many of the victims of Hurricane Katrina. The flood exclusion in homeowner's insurance policies has existed for decades and effectively excludes all water damage directly related to flood. The levelling of homes has led to an inability to differentiate between wind-related damage, which is covered by homeowner's insurance, and flood related damage which is not covered by most of those who lost their homes in hurricane Katrina. Such catastrophic events are likely to lead to increased pay-outs, as well as complexity and uncertainty in settling the claims throughout the insurance sector. If continued indefinitely, this uncertainty is likely to undermine the financial position of reinsurers.

To avoid this level of exposure to loss, the UK insurance industry is engaged with the sectors - such as property, transport and regulatory authorities – domestically, to develop effective and equitable adaptation strategies, for example in revising building regulations and planning controls. Internationally, CII (2001) suggests that key priorities are

- support in the development of climate science modelling
- education of property stakeholders in the potential climate change risks that they face
- co-operation with national governments in: the inventorisation of physical risks; the provision of essential cover/recovery; the accumulation of financial reserves and control of exposure, and; development of new products that share risk.

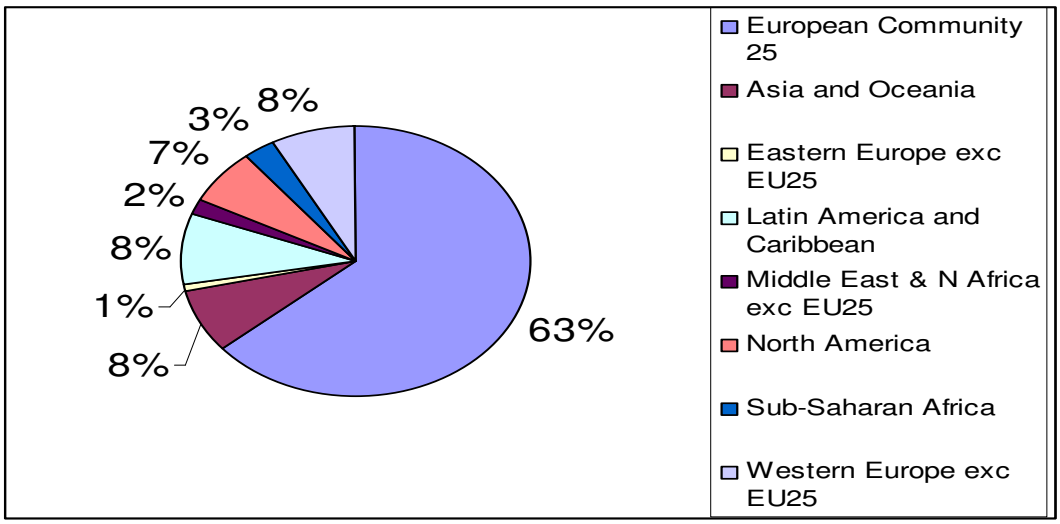
[10] http://www.iii.org/disaster2/facts/FF_flood/

Analysis of Impact Risks to Agricultural Products

The food and drink sector is already vulnerable to adverse weather. In 2007, corn and wheat prices reached their highest levels for a more than a decade, while coffee prices hit an eight-year high and cocoa rose to a four-year high (Flood, 2007). The strength of the coffee price was driven by adverse weather affecting production in Vietnam and Brazil, the two largest producers. Closer to home, the summer 2007 floods across the UK significantly affected agricultural yields, thus driving up prices, (Rozenberg 2007).

The impacts of climate change, as well as mitigation policy, have the potential to negatively affect the food and drink sector in the UK. The food and drink sector in the UK has a sizeable international dimension; as is shown in Figure 2. Raw materials and food stuffs are sourced from a number of world regions, the European Union being dominant. Of the total supplies of raw materials and food stuffs for the UK Food and Drink sector around 16% are sourced from overseas.

Figure 5. Origin of food and drink products imported into the UK, share by value (2006)



Source HM Customs and Revenue 2007

The impacts of climate change on the UK food and drink sector will then, to some extent, be a consequence of changes in the supply of raw materials within the UK and from overseas. For example, we may expect to see changing patterns of global and regional crop distribution and yields. Consequently, the pattern of imports of food and drink products to the UK may change.

Current climate science from the IPCC Fourth Assessment Report suggests that a climatic warming will expand the area of all cereals northwards in Europe. However, warmer temperatures will also lead to an earlier start of growth in the spring and a shorter grain filling period, resulting in reduced yield if management is not altered. Drier conditions in the Mediterranean region may also lead to lower yields there and the need for adoption of new varieties and different crop management schemes. For many vegetable crops, increasing temperature will also generally be beneficial, with production similarly expanding northwards.

A temperature increase will in some areas offer possibilities of a larger span of harvesting dates thus giving continuous market supply during a larger period of the year. For cool season vegetables such as cauliflower, large temperature increases may decrease production during the summer period in southern Europe. In relation to meat, heat stress has several negative effects on animal production, including reduced reproduction and milk production in dairy cows and reduced fertility in pigs. This may negatively affect livestock production in the warm months in the currently warm regions of Europe. Warming during the cold period for cooler regions may on the other hand be beneficial due to reduced feed requirements, increased survival, and lower energy costs. Impacts will probably be minor for intensive livestock systems because climate is regulated to some degree, though requirements for insulation and air-conditioning may change.

It should be noted that these types of change do not necessarily present risks to the food and drink sector, only; there is an opportunity to profit from new products and new markets if firms are willing and able to adapt to this new world order in agricultural production. Root crops, such as sugar beet and potato, for example, are likely to be able to increase their geographical range, leading to lower prices as inputs to many ready prepared meals. However, firms that are unwilling or unable to adapt their production processes and patterns of imports may be threatened by such climate change impacts.

Overview of Approach

In order to assess the risks to the UK Food and Drink sector from climate change it is useful to explore the extent to which raw materials and foodstuffs used in the sector may be impacted upon in their source country or region. More specifically, the agricultural production of these sectoral inputs may be impacted by climate change, e.g. through changes in mean temperature, CO_2 fertilisation, changes in precipitation patterns and subsequent water availability, changes in pest and weed incidence, and changes in the frequency and intensity of extreme events. It is suggested (see e.g. Parry, (ed.) 2000), that such impacts may affect agricultural yields and their subsequent supply price. This section in the case study investigates this possibility and traces through the likely implications for the Food and Drink sector in the UK.

In undertaking this analysis, the overall method we initially adopt is comprised of the following elements:

a) Disaggregate current raw material imports to the UK by country/world region of origin and by food type

b) Review the climate change impact literature in order to identify changes in yields and production for the countries/regions and food types described in a)

c) Map the climate change impacts identified in b) on to the current disaggregated categories of foodstuff imports to the East Midlands

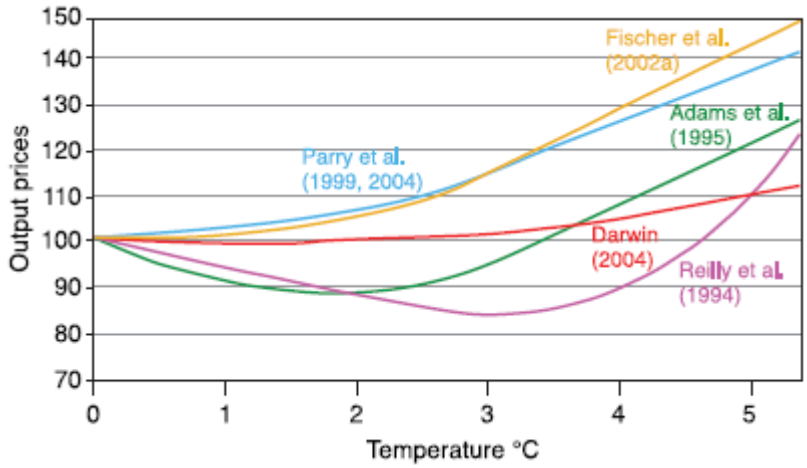
d) Model the climate change impacts in terms of potential quantitative effects on supply price

e) Model the supply price effects identified in d) in terms of potential input cost changes for the East Midlands Food and Drink sector and subsequent effects on profitability.

Note that this methodology assumes that today's pattern of composition and geographical sources of inputs into the operations of the Food and Drink sector in the UK remains unchanged over the future time periods in which climate change impacts are projected. In other words, consumption patterns relating to the Food and Drink sector are assumed to be constant; no socio-economic change is included in the analysis. In reality, this will be a further complicating factor with an uncertain influence on product prices.

Our analysis requires us to identify the changes in costs of the foodstuffs input into the UK Food and Drink sector. Since there are effectively global international markets for foodstuffs we therefore need to identify changes in world prices resulting from climate change; analysis at the individual source country scale is not necessary. An overview of price profiles to 2100 is compiled by Easterling et al. (2007), and presented here in **Error! Reference source not found.**. Note that cereal price changes are used as a proxy for all foodstuffs principally because impact studies of cereals have dominated sectoral studies and are, in any case, likely to be representative of other impacts in the sector e.g. pastureland productivity.

Figure 6. Cereal prices versus temperature increases in global studies



In our analysis we adopt the results from the Parry et al. (2004) study. This is one of the most recent studies and its results constitute a high-end estimate of the possible climate change impacts on commodity prices. The study includes carbon fertilization effects[11] and incorporates the effect of changing trade flows consequent on the climate change impacts on productivity. IPCC SRES socio-economic change (population and economic growth), (Nakicenovic and Swart, (Eds) (2000)), is also built into the trade models, whilst a variety of adaptation responses are also included. The results for the A2 (medium-high) emissions scenario are adopted. Note that there is very significant uncertainty in this approach; a lower-end estimate e.g. from Darwin (2004) is likely to lead to insignificant impacts over the time period considered[12], and can be understood to have the same likelihood.

The changes in food prices identified by Parry et al. (2004) are interpreted in our analysis in terms of changes in input costs to the Food and Drink sub-sectors. An own price elasticity – assumed to be of 0.5 – dictates the extent to which the cost increases can be passed on to

[11] The enhancement of plant productivity due to higher atmospheric carbon dioxide levels.

[12] Note that whilst the two earlier studies – Darwin et al. (1994), Adams et al. (1995) – project price falls for low levels of global mean temperature increases, and suggest possible commercial opportunities deriving from lower input costs, their results are based on what are now considered to be unrealistically high levels of carbon enrichment. Consequently, we suggest less weight be given to the lower end results.

consumers. The resulting changes in input costs borne by the firms within the sub-sectors are then expressed in terms of the percentage by which they reduce the Gross Operating Surplus (GOS), adopted as a proxy for profit levels.

Results

The estimated changes in costs, as a percentage of the GOS, are presented in Table 1 for the UK for 2004 (from Eurostat data). The four sub-sectors whose profitability is most vulnerable under the future climate change-induced price scenarios are highlighted in the table, in bold italics: Production and preserving of Meat and Poultry Meat, Operation of dairies and cheese making, and Manufacture of prepared feeds for farm animals. In these sectors, profitability is reduced by 10-20% in the 2020s and by 20-40% in the 2080s. Other sub-sectors' profitability is generally negatively impacted by under 5%.

Table 5. Cost increases expressed as % of UK Food & Drink sub-sector GOS in future time-periods

Sub-sector	2020s	2050s	2080s
Production and preserving of meat	***12.4***	***14.3***	***24.8***
Production and preserving of poultrymeat	***11.1***	***12.9***	***22.3***
Production of meat and poultrymeat products	7.4	8.6	14.8
Processing and preserving of potatoes	1.8	2.1	3.6
Processing and preserving of fruit and vegetables	4.6	5.3	9.3
Operation of dairies and cheese making	***19.5***	***22.5***	***39.0***
Manufacture of ice cream	2.4	2.8	4.9
Manufacture of prepared feeds for farm animals	***19.5***	***22.5***	***39.1***
Manufacture of bread, cakes etc	2.9	3.4	5.9
Manufacture of rusks and biscuits	3.4	4.0	6.9
Manufacture of cocoa; chocolate and confection	1.6	1.8	3.2
Processing of tea and coffee	2.0	2.3	3.9
Manufacture of condiments and seasonings	3.9	4.5	7.9
Manufacture of other food products	3.2	3.7	6.4
Manufacture of beverages	1.6	1.8	3.2

Clearly, these estimates hide significant uncertainties, not only due to the assumptions adopted but also in the climate change scenarios and climate impact (price change) modelling. It should also be remembered that these estimates are likely to constitute the high end of estimates since the price changes adopted are from a medium-high climate change scenario within a study that gives larger adverse price changes than other similarly designed studies. A lower end to the price range is provided by the Darwin et al. (2004) study which effectively projects unchanged prices at lower global mean temperature increases. For reasons given above, however, we place less weight on these lower end results.

Additionally, we assume that all foodstuff inputs to the Food and Drink sector are affected by the projected price increases. However, the UK is a temperate country which, is not expected to be as adversely affected as some other source countries. To the extent that there are domestic markets in foodstuffs not impacted by changes in global markets, this suggests that

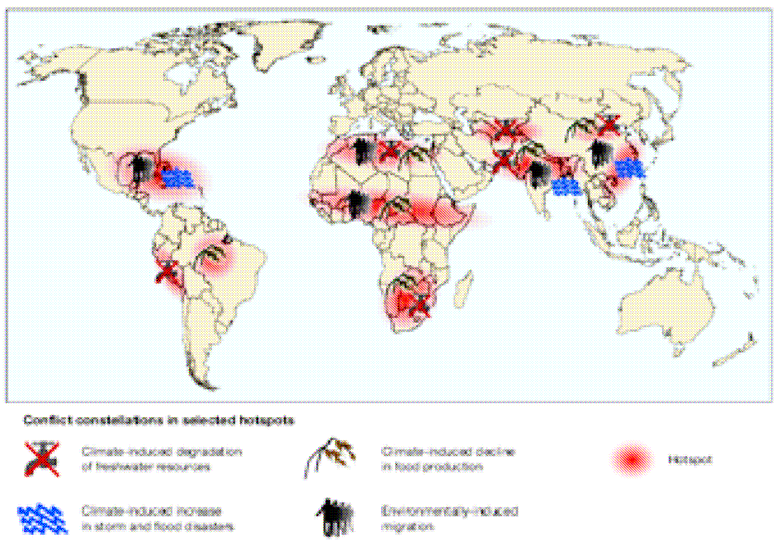
– since imports constitute only 16% of total foodstuffs used in the UK – the negative impact may be much reduced.

The analysis is clearly partial in its coverage of uncertainty and limited in its basis in current rather than future socio-economic conditions. Nevertheless, it provides a first indication of the scale of impact that may be faced by certain UK industrial sub-sectors. Adaptation actions are therefore likely to focus, in the short term at least, in developing a more sophisticated and robust modelling approach to such economic changes. If impacts – negative or positive – are established more clearly, there would be merit in encouraging flexibility from, and to, sectors and sub-sectors that minimise future vulnerability and maximise financial opportunities under climate change scenarios.

Migration and Conflict

The focus on migration and security in this sub-section arises from a growing awareness, expressed most recently in the Swedish national climate change impacts study, referred to above, that other, less sector-specific, policy areas, will be dependent on events in other, often poor, parts of the world as a result of climate change. For example, there is a recognition that security policy may need to be integrated further with aid policy in future. Through comprehensive humanitarian interventions and peace-building, it is possible to prevent the destabilisation of regions, famine disasters, the spread of epidemics, flows of refugees, etc. A map presenting potential geographical hot-spots of this nature – taken from the Swedish study - is given below.

Figure 4.54 Potential trouble spots resulting from climate change



Source: WBGU, 2007.

Migration

The spectre of waves of migrants moving from more vulnerable world regions to wealthier northern hemisphere countries such as the UK has periodically been conjured up in media reports of future climate change. Recent research emphasises, however, that the mechanisms that determine migration – and including those that induce migration as a result of climate change – are complex and non-linear. As a consequence, the scale of potential migration

remains speculative, and the means by which to prevent migration requires more attention. These strands of current research are reflected in this sub-section. Since conflict often arises as a result of migrants competing for resources in the destination location, we also review this issue here.

Forced climate migrants, with which we are concerned here, are those people who involuntarily leave their current homes as a result of climatic conditions. This accords with the definition of environmental migrants proposed by the International Organisation for Migration (IOM) as "persons, or groups of persons, who for compelling reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or chose to do so, either temporarily or permanently, and who move either within their country or abroad."[13] A further distinction to be made is that between migration as a hurried response to an extreme event, ex post, and migration as a more planned response to a steadily deteriorating situation.

It is relatively simple to imagine that forced climate migration may result from a diminishing water and food supply brought about by increased variability in rainfall patterns, migration of local fish stocks, or flooding from sea-level rise that inundates scarce productive agricultural areas along coastlines. Attendant health risks from malnutrition and diarrhoeal diseases, as well as changing distributions of vector-borne diseases may also be significant. These threats are most relevant for many African countries, Small Island States, and Central, East and South Asia, (Parry et. al., 2007). The same world regions are also expected to be particularly vulnerable to extreme weather events such as windstorms, intense precipitation or droughts that may damage, disrupt or destroy property and infrastructure and so lead to forced migration. It is also possible to envisage mean temperatures rising to levels that physiologically prohibit many human activities and plant or livestock growth in Equatorial regions, leading to forced migration.

Authors such as Brown, (2008), emphasise, however, that migration should be seen as a combination of both "push" factors, such as climatic conditions, and "pull" factors, such as economic opportunities that may exist in the destination location. As with many areas of climate change impact assessment it is also important to be clear that other, non-climatic, factors may be at least as significant in determining migration factors. In Africa and Asia, for example, where forced climate migratory pressure appears to be most likely, demographic factors such as population growth, as well as resource depletion patterns, contribute to the migratory pressure.

However, Brown also stresses that migration is a function of mobility which – itself – is determined by financial resources. Thus, the distance which an individual or family can migrate may be constrained by how much they can afford to pay in travel costs, as well as accommodation costs in the destination location. Other factors such as land ownership rights, the efficacy of pooled resources within extended families and communities, information provision on socio-economic conditions in the destination location, the extent and form of state support etc. are all likely to help determine decisions at the family level. These factors also help to make clear that – except, perhaps, in the case of a devastating extreme weather event – the term "forced" is a relative one.

Perhaps partly as a result of the complexity of the mechanism that determines forced migration, quantitative empirical estimation of the potential scale of climate change-induced

[13] IOM, "Discussion note: Migration and the Environment;, Ninety-fourth session, MC/INF/288, 2007, p1-2.

forced migration is scarce. The large-scale movements resulting either from conflicts or from rural to urban areas currently observed are difficult to attribute to climate variability and climatic change, solely, though they may be important factors. Additionally, there is little data that can be used, and provision for monitoring future migratory movements are limited in the most vulnerable regions.

However, Myers (2002) suggested that 25 million people globally had migrated by 1995 primarily as a result of climate, and scaled this figure to 50 million by 2010. Myers (2005) projected a total of 200 million forced climate migrants by 2050, later up-dated to 250 million (Christian Aid, 2007). The method by which these numbers are derived is not presented. It is also worth considering that whilst 200 million is a large number it fits in with the extent of migrations currently observed. For example, UNFPA, (2007) suggests that 350 million people are anticipated to move from rural to urban areas in China alone, reflecting a broader symptom of economic development.

Brown (2008) presents migrant numbers dependent on three climate-socio-economic scenarios, using the IPCC SRES. These numbers appear to be derived on the basis of a simple scaling related to numbers of people suffering water scarcity, hunger and flood risk from sea-level rise, though the method is not made explicit.

- The SRES B1 scenario is presented as a best case, with a global population peaking by 2050 at 9 billion before declining subsequently. Additionally, atmospheric concentrations of CO^2 are projected to stabilise at 600ppm by 2100, corresponding to a 1.8^{o}C temperature increase and sea level rise of 18-38cm. Crop yields in Africa are projected to fall by 5-10%. Brown suggests a 5-10% increase in migration from current volumes, though rural-to-urban movements do not change.

- The SRES A1B scenario results in a mid-point 2.4^{o}C temperature increase and atmospheric concentrations of CO^2 by 2100 are projected to be 850ppm. A total of 150 million to 550 million people would be expected to be at risk of hunger. In this scenario, rural-to-urban and international migration would result, the latter being comprised of young and skilled people.

- The SRES A1F1 scenario projects atmospheric concentrations of CO^2 of 1,550ppm by 2100, equivalent to a mid-point temperature increase of 4.0^{o}C. A decline in water availability of 30-50% in Southern Africa and the Mediterranean region is projected, with sea level rise of 29-59cm. Brown suggests that, "predictions of 200 million people displaced by climate change might easily be exceeded." Furthermore, "large areas of southern China, South Asia, and the Sahelian region of sub-Saharan Africa could become uninhabitable on a permanent basis."

The other – equally small - body of empirical evidence available centres on local-scale case studies that examine the relative strengths of the various push and pull factors involved in families' decision-making related to migration. Mortreux and Barnett, (2009), for example, explore the extent to which climate change is currently perceived as a factor in determining migratory patterns on the island of Funafuti, Tuvalu – a small island state. They find little evidence of the population including sea level rise and other impacts associated with climate change as being influential in current or future migration plans. Other studies – such as those

collected in the special issue of Forced Migration Review[14] in October 2008, on Climate Change and Displacement – provide evidence that climate variability and change is an important determinant of current migratory factors, though rarely the only one.

The empirical evidence gives the overall impression that, whilst there is substantial uncertainty in the future extent of forced climate migration, due primarily to the severity of global climate change itself, there is the potential for current migratory trends to be significantly exacerbated. The majority of such migratory pressure is likely to be borne at the national or regional level. There is also, however, the likelihood of increased pressure of immigration to developed countries such as the UK under more severe climate scenarios, towards the middle of the 21st Century.

It might be expected that the UK is most likely to be susceptible to migratory pressures from former Commonwealth countries in South Asia, the Caribbean, and East Africa that are vulnerable to climate change and that have large diaspora populations in the UK. This pattern reflects the pattern of migration applications that have arisen from conflicts in these regions. From the evidence presented above, however, the extent of such pressures remains very uncertain.

There is a view that any such migratory pressure from LDCs to DCs should be accommodated on the basis of equity; a form of compensation for the greenhouse gas emissions resulting from historical development (NEF, 2007). Moreover, there is some evidence (see e.g. McMahon, 2003), though disputed by e.g. Coleman and Rowthorne, (2004), that large-scale in-migration to the UK may have net economic benefits. However, it is likely, for reasons relating to social and cultural values that Mortreux and Barnett (2009) document for Tuvalu, people would prefer not to migrate. Instead, the primary role for the UK in relation to climate-forced migration is to facilitate development generally, and increase in adaptive capacity specifically in the regions most vulnerable to climate change, and where climate change is most likely to trigger forced migration. There are also a number of migration-focussed adaptation actions that may be supported by the UK. These include:

- Case-study and regional-scale research into the size and location of migration potential, to allow future planning and response
- Enhanced monitoring and early warning

- Co-ordination to support the full spectrum of different refugees or IDP and forced migration between different international actors (rather than the current cluster approach)

- Encouragement of greater acceptance on migration, example of New Zealand promising some resettlement for south pacific islands an example. Note that people offered resettlement don't always take it, but it is important as an option to them

<u>Conflict</u>

The same argument for UK support to development as a primary form of adaptation in order to prevent forced migration adaptation applies to the treatment of conflict, and its prevention. Indeed, conflict can be seen as an alternative response to migration when resources integral to a community, or other grouping of people, become more scarce, such that fighting over the remaining resources arises, rather than looking elsewhere. As with climate-forced migration,

[14] Forced Migration Review, October 2008, No. 31. Refugees Study Centre, Oxford Department of International Development, Oxford University.

empirical evidence is almost entirely qualitative and based on assertion. Nordås and Gleditsch (2007) provide a recent overview of this evidence base. They find that whilst conflict might in principle occur in various forms (non-state or state, armed or not), either where the climate impact on resources is greatest, or at the destination of a migrant population resulting from climate change, historical evidence shows that co-operation is much more likely than conflict. This has been witnessed in the context of competition for water resources in various international contexts (Yoffe, Wolf and Giordano, (2003)). Certainly, where conflict does result it seems often to reflect pre-existing ethnic divisions (Reuveny, 2007), though Nyong, Fiki and McLeman find that drought conflicts in the Western Sahel have been increasing and that climate change could exacerbate such conflicts.

As a result of the potential impacts outlined above, there may be increased pressure on international governance. For example, it is possible that climate change impacts could fuel the politics of resentment between those most responsible for climate change and those most affected by it. Impacts of climate mitigation policies (or policy failures) could thus drive political tension nationally and internationally. The potential rift not only divides North and South but there will also be a South - South dimension, e.g. as the Chinese and Indian share of global emissions rises. The already burdened international security architecture will be put under increasing pressure.

Nordås and Gleditsch (2007) do also recognise the possibility that international terrorism may be encouraged by resource scarcity and deprivation exacerbated by climate change. However, they concur with the view of Barnett and Adger (2007), who argue that developing countries will bear the brunt of any climate change-induced conflict, and other forms of impacts and responses to climate change.

Concluding remarks on migration and conflict

The sub-sections above relating to the dual responses to climate change vulnerability paint an overview of the factors that determine such responses. It becomes clear that the nature and scale of such responses are determined by the balance of these individual factors, making quantified projections a difficult research task. However, it is also clear that these responses have potentially important repercussions for the UK and other, wealthier countries. In order to help scope future research efforts, Table 6 below outlines a schematic that highlights the roles of various factors in determining these responses. The table content is indicative rather than comprehensive. However, it does serve to emphasise that future research should develop the ability to model more robustly – using scenario analysis – the linkages between climate change, its impacts, and possible responses – either reactive or anticipatory, and domestically or internationally.

Table 6. Determinants of climate change-induced migration and conflict

<table>
<tr><th>Climatic variable(s) leading to climate impact</th><th>Climate impact</th><th>Factors determining migration response</th><th>Factors determining conflict response</th><th>World regions vulnerable & likely to impact UK</th></tr>
<tr><td rowspan="2">Mean temperature increases</td><td>Crop tolerance thresholds breached → fall in agricultural output</td><td>Lack of permanent possibilities for alternative agricultural output;
Economic opportunities in urban areas (domestic)
Economic opportunities (international - UK)</td><td rowspan="5">Access to resources (local, domestic, international – UK).

Potential for conflict exacerbated by cultural differences between population groups involved, including from in-migration;

Effectiveness of rule of law and internal security.</td><td rowspan="5">South Asian Sub-Continent

Sub-Saharan Africa

Caribbean</td></tr>
<tr><td>Physical limits on human physical activity</td><td rowspan="2">Lack of possibilities for alternative raw materials and/or livelihoods;</td></tr>
<tr><td rowspan="2">Mean precipitation declines (annual & intra-annual</td><td>Ecosystem tolerance thresholds breached</td></tr>
<tr><td>Water availability for human use declines</td></tr>
<tr><td rowspan="2">Extreme weather events: precipitation, wind or temperature; storm surge.</td><td>Annual or inter-annual crops destroyed or disrupted</td><td>Lack of temporary alternative economic opportunities locally or domestically</td></tr>
<tr><td>Domestic or business property damaged</td><td>Lack of alternative temporary accommodation</td></tr>
</table>

Section 4. Conclusions and Recommendations for the planned UK Climate Change Risk Assessment

This report has presented an initial scoping of the range of global climate change impacts projected to result in potential consequent impacts on the UK. An initial, broad, scoping of these impacts identified that the forms in which they may manifest themselves are various. They may include:

- Changes in the prices of raw materials and final products to UK-based businesses and consumers;
- Disruptions to the overseas supply chains and operations of UK businesses;
- Changes in patterns of human movements, in the form of tourism and migration, and their effects of business and infrastructure in the UK;
- Implications for humanitarian and development aid as a result of changes in resource scarcity and extreme weather events.

However, a consistent finding from the various sectoral assessments was that two factors complicate the picture. First, the mechanism by which climate change might translate into these types of impacts, and their extent, is determined to a greater or lesser extent on other socio-economic characteristics. As a consequence, in many instances it is very difficult to attribute the potential impacts to climate change alone. Migratory and conflict-based impacts are prime examples of these; they therefore make justification of climate change mitigation policy on grounds of their avoidance, more challenging. Second, the uncertainties remaining in the causative pathway from greenhouse gas emissions to direct and indirect impacts are very considerable. As a consequent, quantification of impact risks remains limited, making robust adaptive actions difficult to design and undertake. However, to the extent that adaptive actions are no-regrets based – as with development assistance – this difficulty is mitigated.

On the basis of this scoping exercise, we make the following suggestions for the inclusion of international impacts in the UK Climate Change Risk Assessment being planned:

- Undertake a more comprehensive mapping of potential indirect climate change impacts on the UK. This could have the following components:

    a. a stakeholder-based consultation exercise, designed to assess the degree to which impacts identified in the scoping exercise are perceived to exist currently or in the future, and the types of adaptation response most likely to be effective;

    b. a mapping of impacts on a regional and sub-regional basis and an identification of potential "hot spots" of particular consequence for the UK, e.g. from where multiple impact types derive, or from where UK-based diaspora originate;

    c. a more rigorous description and parameterization of the uncertainties associated with indirect impacts identified;

    d. an assessment of the types, and potential extent, of the costs and benefits of the impacts identified to the different stakeholders involved, in both the source countries and the UK. It is anticipated that such an assessment will also

emphasise any distributional consequences of the impacts or adaptation actions that can be identified.

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Annex 1: Summary of International Sectoral Impacts of Projected Climate Change, Associated Impacts on the UK, and possible UK Adaptation Responses

Sector	World region	Vulnerable regions	Direct Impacts	Anticipated Effects on UK	UK adaptation strategies
Water supply and quality, including sea level rise	Africa, Asia, Australasia, Latin America, North America, Polar Regions	• Antarctic Peninsula regions • West Antarctic ice sheet • Greenland ice sheet • Coastal settlements in the Gulf of Guinea, Senegal, Gambia, Egypt and the East – Southern African coast	• Current water stresses in Africa and Australasia are likely to be compounded by 2020s and 2050s in Asia. In Latin America, lower rainfall will cause serious water shortages, e.g. in Argentina, Chile and Brazil between 7 million and 77 million people could be affected by the 2020s • Increased need for agricultural irrigation – 10% with every 1^0C rise in temperature in East Asia • Increased risk of floods and landslides thereby compromising water quality • Reduced access to fresh water, e.g. in India by 2025. Compounded by population growth. • Sea level rise and coastal inundation by end of 21st Century in Africa • Displacement of inhabitants in mega delta regions of Asia caused by sea level rise and flooding • In southern and eastern Australia and New Zealand, water problems will be exacerbated, e.g. 0-30% decline in run-off by 2030 in Victoria • Coastal vulnerability in North America, disruption to transport and infrastructure on Atlantic Coast as sea level rises and tidal surges increase • Thawing of permafrost and melting of glaciers, ice caps and ice sheets	• Increased demand for water on the world market making it a very marketable, and scarce, commodity. • Water scarcity and flooding will both become increasingly important issues in the UK's security and aid policies. As water shortages overseas increase, the UK may be forced to become highly efficient in its use of water resources, e.g. more frequent hosepipe bans. • There may be increased migration to the UK as coastal displacement occurs • Negative impact on UK organisations with companies overseas in coastal areas who may need to relocate inland or back to UK.	• International water trading, including exports from the UK, is likely. • Possible export provision of water resource management and coastal defence engineering. • Management of potential immigration to the UK from world regions vulnerable either to significant water resource constraints or to inundation from sea-level rise.

Sector	World region	Vulnerable regions	Direct Impacts	Anticipated Effects on UK	UK adaptation strategies
Food and agriculture, including fisheries	• Africa, • Asia, • Australasia, • Latin America, • North America • Europe	• The Sahel and Great Lakes region, East Africa are likely to be particularly affected by water shortage and land denudation • Multi-regional impacts on agriculture and fisheries productivity	• South East Asia likely to see an increasing grain harvest. • Africa is projected to experience an increase of 5 to 8% of arid and semi-arid land by the 2080s leading to reduced agricultural yields, increased desertification and drought • Benefits seem more short/medium term (up to 2050) while the long-term impacts seem negative. • Reduction in rice yields beyond 2020, but rise in soybean yields in Latin America • Reduced cattle productivity as temperature increases in Latin America • Rise in number of people at risk of hunger in Latin America, from 5, 26 and 85 million in 2020s, 2050s and 2080s respectively • In North America & Europe, rain-fed agricultural yields are set to increase early in the 21st century • Migration & changes in quantity of global fish stocks	• Reduced supply of foodstuffs on the world market (especially in the long run) could result in the UK being food insecure in products imported from abroad. Potential loss of rice crop supplies from Asia by mid 21st century making it more difficult and expensive to import into the UK. • Impacts on UK fishing industry catches	• Could create opportunities for British agriculture in foreign markets • UK policy may reflect the need to source food locally, potentially cutting costs and reducing 'food miles' associated with international food markets. This could also reduce the risk of disruption to food supplies • UK Government may be obliged to increase aid for food supply and • immigration to UK may increase as famine increases • Adjustment of UK fishing quotas; local economic diversification

Sector	World region	Vulnerable regions	Direct Impacts	Anticipated Effects on UK	UK adaptation strategies
Health	Africa, Asia, North America, Europe	Africa, Asia	• Negative effects in Asia and Africa, increased spread of Malaria, diarrhoea and infectious diseases • Populations in North America, especially the elderly, are likely to experience health issues associated with increased frequency and erratic heat waves • Increased occurrences of Schistosomiasis, Denge and Malaria in island nations as the boundaries of many disease-borne vectors change.	• UK can be impacted by the increased risk of the spread of infectious diseases, affecting national health and travel/immigration policies • ODA will also be influenced by the deterioration of health in the Developing World	• Preventative national health policies including inoculations • Reactive capacity to cope with infected tourists returning to UK • ODA targeted at sanitation and health
Tourism	Africa, Asia, Latin America, small islands	All	• Degradation of coral reefs and mangroves by 30% in next 30 years, e.g. Mekong River delta in Asia, leading to impacts on fisheries and creation of salt marsh habitats. Also in Brazil and Columbia and by the end of 21st century in Africa. Mesoamerican coral reefs in Mexico, Belize and Panama likely to be affected. • Coastal degradation by 2050s in Australia and New Zealand as development increases and reduces ability of coast to cope with storms and sea level rise. This could lead to reduced beach area, unattractive to tourists. • Sea level rise in Latin America, e.g. Uruguay and Mexico, may affect tourism • Increased frequency of tropical storms • Small islands including Barbados, Maldives and Seychelles are likely to become less attractive as tourist destinations as water becomes scarcer.	• Potential loss of quality of overseas tourist destinations for UK residents. • Increase in eco-tourism may cause the cost of holidays in these destinations to rise in an attempt to protect threatened resources such as coral reefs and mangroves. • Perception of danger of such destinations may increase with rising frequency of storms in Latin America, so UK residents may be more likely to take domestic holidays. Positive impact for UK economy and commerce.	• Investment in UK tourism infrastructure
Forestry	Asia, Australasia		• Increased frequency and magnitude of forest fires in northern Asia as temperatures rise and drought increases • Decline in forestry production by 2030 in	• Loss of wood sources • Disadvantages include impact on biodiversity if not well managed • As wood becomes scarcer, it will	• May encourage greater production and stronger markets in UK.

Sector	World region	Vulnerable regions	Direct Impacts	Anticipated Effects on UK	UK adaptation strategies
			southern and eastern Australia, eastern New Zealand from forest fires and drought. Potential benefits in New Zealand from fewer frost days and higher rainfall • At start of 21st century, forestry production in North America is likely to increase. This will however be at greater risk from storms, drought and pests.	become more expensive to import to the UK. Furniture companies and other end-users will have to absorb this cost, making their goods more expensive. Potential rise of living cost for UK buyers.	
Ecosystems and Biodiversity	Australasia and Latin America	Australia and New Zealand likely to be particularly effected, by significant losses up until 2020.	• Alteration of ecosystems by 2020 including Great Barrier Reef, south-western Australia, Kakadu Wetlands, rain forests and alpine areas. This may lead to habitat loss, species extinction, reduced ecosystem services (fishing, forestry, water supplies) • Increased risk of forest fires in south-east Australia – 4 to 25% by 2020s and 15 to 70% by 2050s • Habitat change in Latin America, as temperature increases and soil moisture content decreases, turning tropical rainforests into savannahs, e.g. in eastern Amazonia and central-southern Mexico. • Increased loss of coastal wetlands as sea level in North America increases. In north-eastern marshes, salt marsh biodiversity may decrease • As conditions in Polar Regions become less harsh, alien species are more likely to migrate to Arctic and Antarctic regions, threatening the survival of polar species such as bears and seals. • It is projected that by the end of the 21st century, forest will replace between 10% and 50% of existing Arctic tundra, and tundra will replace 15% to 25% of existing polar desert	• Potential loss of raw materials. • May exacerbate risk of conflict and migration	• ODA targeted at ecosystem management
Business and	Australasia		• Risks from sea level rise and flooding,	• Damage to property	• UK companies with

Sector	World region	Vulnerable regions	Direct Impacts	Anticipated Effects on UK	UK adaptation strategies
infrastructure			where flood plains and coasts have been heavily developed • Increase risk of power shortages and black outs as temperatures rise thus increasing demand for air conditioning	• Impact on labour force health	offices, factories or sites overseas to exploit cheaper labour costs may be forced to relocate back to the UK, thus increasing costs of production and service provision.
Energy	Latin America		• With the loss of inter-tropical glaciers, there will be reduced water availability and less potential for hydro-power generation by 2025 in Bolivia, Peru, Columbia and Ecuador		
Infrastructure	North America		• The cost of damage from tropical storms may increase by 70-75%	• UK companies with offices in the North America region could suffer large scale losses from the potential damage.	• Construction and building sector in the UK could exploit it as a business opportunity and grow in strength.
Conflict	Africa, Middle East, South Asia	Africa	• Increasing scarcity of natural resources, especially food and water has raised concern increased conflict. “Water wars”, civil conflict in Darfur etc are likely to exacerbate as a result of climate change.	• Unstable regional and hence world economy, impacting the imports and exports of the UK.	• Increased military budget and need for more troops being sent abroad. • OCA targeted at resource management

Sources for Annex Tables

Parry, M.L., O.F. Canziani, J.P. Palutikof and Co-authors 2007: Technical Summary. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 23-78.

Johnston. K (2008); “Climate Change: A Cause of Conflict?” *Global Politics Magazine*

Note: All projections based on IPCC SRES projections (AR4)