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Assessing climate risks across different business sectors and industries: an investigation of methodological challenges at national scale for the UK

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Paper: Assessing climate risks across different businesses and industries– reflections on methods and approach from the UK Climate Change Risk Assessment process

Abstract

Climate change poses severe risks for businesses, which companies as well as governments need to understand in order to take appropriate steps to mitigate their effects. This however represents a significant challenge as climate change risk assessment is itself a complex, dynamic and geographically diverse process. Risks to businesses are further complicated by aspects such as the nature of the value chain creation, the location of the business and relationships and interdependencies with customers and suppliers. This research explores these methodological challenges for a national-scale assessment of climate risks through the lens of the UK Climate Change Risk Assessment (UKCCRA) process and compares the approaches adopted in the first and second UKCCRA (2011, 2016), while also reflecting on international experiences elsewhere. A desk-based review of these issues is presented, drawing on a wide body of contemporary evidence from a range of sources including the research disciplines, grey literature and government policy. The study reveals the methodological challenges and highlights six broad themes, namely scale, evidence base, adaptation responses, scope, interdependencies, and public policy. The paper concludes by identifying suitable lessons for future national climate risk assessments, which should guide the next phase of research in preparation for UKCCRA3.

Keywords

Private sector Adaptation, Climate Change, Climate Change Risk Assessment, business and industry, UKCCRA

1. Introduction

Climate change risk assessments are an important element of climate adaptation. Indeed, the global spectrum of political frameworks, such as the United Nations Framework Convention on Climate Change (UNFCCC) and its Warsaw International Mechanism for Loss and Damage (L&D), and the Sendai Framework for Disaster Risk Reduction (SFDRR), all underline the importance of evidence-based risk assessment to guide public policy. Thus, there are a range of national assessments being conducted, aimed at improving the understanding of current and future risks as well as providing guidance to those tasked with making adaptation-related decisions. Including risk and

opportunities for business and industries in those assessments is important but not without challenges.

It is widely accepted that climate change can influence the ability of business and industry to produce goods and services. These impacts can be immediate, for example, if flooding causes a business to close temporarily, or they can occur over time in a more dynamic sense, for example by increasing the costs of operating in a specific location to the point where relocation or closure are the only viable option for the business.. Furthermore, a business can experience direct impacts, such as business interruption and damage to physical assets in case of a windstorm, or indirect impacts through public policy or market changes such as rising demand for flood resilient materials or increased competition for certain resources. [1, 2]

In this paper the concept of climate risks faced by businesses is in line with the approach used in UKCCRA (UKCCRA2), which investigates ‘the risks posed by extreme weather events and the anticipated longer term climate change on business and industry in the UK’. This includes the influence of the current climate variability as well as future climate change affecting businesses and their strategies through physical risks, reputational risks, regulatory risks and litigations risks. UKCCRA2 also highlights that there are specific sectors such as engineering and consulting, tourism, insurance and other finance products, agriculture, food and utilities, where the effect of current climate variability is more pronounced both in terms of risks and opportunities. Bhattacharya-Mis and Lamond (2014) for instance show that uninsured losses from extreme weather events may result in heavy secondary losses for banks, to emphasise not just the cascading impacts but also the longer term climate change risks that should be taken into consideration in policy making [8].

Understanding these climate change risks matters – to companies in order to prepare, reduce risks and take advantage of any opportunities that might arise; and to governments because risks to businesses impact the economy as a whole and because company behaviour plays an important role in determining current and future risk levels (e.g. when businesses make investment decisions). [9] However, it is important to recognise that the scale and level of detail of climate change risk assessments will be different between companies and government. Companies are likely to need to understand the risks and opportunities at a site-specific scale, and / or across their value chain, in order to make timely and robust decisions about how to adapt; whereas government is more interested in the risks and opportunities facing specific broad-scale business and industry segments, components of the value chain and / or the economy as a whole. Nevertheless, the two processes are happening in parallel – some of the larger companies are undertaking their own risk assessments and reporting their findings through annual Corporate Social Responsibility and Sustainability reporting and voluntary disclosures [10, 11, 12] (e.g. Climate Change Act’s Adaptation Reporting Powers, Carbon Disclosure Project, Task Force on Climate-related Financial Disclosures),

which government is then using as an evidence base of the risks facing the private sector and the actions being taking [13, 14] (e.g. Adaptation Sub-Committee Progress reports, Climate Ready publications). Conversely, government is publishing higher-level and sector-specific summaries of the risks facing the business and industry, through the national CCRA process and other publications listed above, which companies, who may not have already undertaken their own risk assessment, are using to understand their exposure to climate risks. The analysis that follows focuses exclusively on the needs of government.

Whether or not a climatic event such as a flood or drought has already or is likely to have consequences for businesses depends on the complex interplay of multiple determinants of risk: hazard, exposure and vulnerability together determine the risk for a business or a sector or the economy as a whole. Capturing this in a risk assessment is challenging, as risk is not static, but dynamic, multifaceted and regionally as well as locally diverse. [15, 16] Aspects such as the nature of the value creation chain, the choice of location of business operations, and a company's relationships with customers or suppliers all influence risk levels, as highlighted in recent sectoral reports, such as from the World Business Council for Sustainable Development exploring the range of climate risks for companies in the energy sector, or at the European level, a report addressing the impact of climate change on the tourism sector. [17, 18]

While climate change risk assessments have become more sophisticated thanks to better data, clearer understanding of the risk processes and a broadening of assessment tools (see for example JRC [19]), there are certain aspects that pose considerable methodological challenges for assessing climate change risks to businesses and industries: the channels through which climate can influence businesses are very diverse and can span many continents, requiring the recognition of domestic as well as international aspects. The indirect impacts often outweigh direct risks, for example through market fluctuations, [20] but are harder to evaluate. Importantly, there are also a range of interdependencies at play – such as an actor's choice to take adaptive action, which can influence the risk levels of others, for example in the context of shared resources at neighbouring locations or across a supply chain. And the evidence base is often limited, usually based on company reports, case studies or surveys, which vary in quality, scale and scope.

In this paper we explore these methodological challenges through the lens of the UK Climate Change Risk Assessment (UKCCRA) process, which requires the UK government to publish a UK wide climate risk assessment every five years.

In order to address the risks identified by the first UKCCRA (UKCCRA1), the Government commissioned a study to develop an economic framework for adaptation. The Economics of Climate Resilience (ECR) study assessed the extent to which organisations would be able to adapt autonomously, and the extent in which the Government should

intervene to fill the adaptation gap. The UKCCRA2 applied a similar framework in identify the urgency of the risks that required Government interventions (see Annex 4). The scope of each of the UKCCRAs is to identify key climate change risk and opportunities, in order to inform a national adaptation plan setting policies and actions to address them. Across the paper, a comparison between UKCCRA1 and UKCCRA2 is drawn in order to assess the progress and lesson learnt between the first and the second assessments, and highlight further gaps that could be overcome in the third assessment, due in 2021. The comparison is made by looking at the different aims, methods and findings (both in terms of the extent as well as substance) from the first two assessments. The UKCCRA1, conducted in 2011, took a traditional sectoral approach to understanding climate risks across key business and industrial sectors. [21] The UKCCRA2 however had a different remit, specifically requesting the consideration of adaptation responses in the assessment: ‘based on the latest understanding of current, and future, climate risks/opportunities, vulnerability and adaptation, what should the priorities be for the next UK National Adaptation Programme and the adaptation programmes of the devolved administrations?’ [22] UKCCRA2 thus shifted the focus away from a narrower and domestically oriented concept of determining risk levels and broadened the assessment to include adaptation behaviour, the role of public policy, as well as international aspects and interdependencies across risks and different types of business activities.

We investigate the methodological advances between the two UKCCRAs, reflect on experiences elsewhere, and outline emerging research gaps for the assessment of risks to business and industry. A desk based review of these issues is presented, drawing on a wide body of contemporary evidence from a range of sources including the research disciplines, grey literature and government policy. The study also benefits from the unique insights and experiences of the authors, many of whom were contributors to UKCCRA2.

2. Methodological challenges for assessing climate risks to business and industry

The assessment of climate risks needs to consider information about current and future hazards, exposure and vulnerability. This requires decisions on a range of issues, including the assessment’s time-frame (e.g. which future impacts to consider), the type of climate scenarios to use, which hazards to cover, what impacts to investigate and what data to use. For example, Fellman [23] shows how risk assessments can differ in how they conceptually understand vulnerability (e.g. as an ‘outcome’ or the ‘starting point’ of a risk assessment), in the methods they utilise and with regards to the impact of data uncertainty (e.g. biases and noise in data). For a more detailed discussion of these general methodological challenges, see Warren et al., forthcoming [24] and Warren et al. [25].

In addition, there are several aspects that are particularly relevant to the assessment of climate change risks for business and industry. A review of the academic literature and a survey of recent examples of national climate risk assessments (see Appendix 1 for details) identified six aspects that require attention when investigating climate change risks to business and industry as part of a national climate change risk assessment: the scale of the investigation, the treatment of evidence and scope of the impacts considered, adaptation, and the consideration of how complex business processes and relationships (i.e. interdependencies), as well as public policy and regulation influence risk levels. These are summarized below.

Scale

Assessing climate risks to business and industry raises the difficulty of capturing the significant risk variations across sub-sectors, types of businesses and industries. The most common approach to scale is a sectoral focus, based on the understanding that climate change impacts on sectors vary. [26] Under-pinned by sector-specific risk assessments such as the energy, water, transport, tourism and insurance sectors which were extensively discussed in the IPCC 5th assessment report, there is an understanding that factors such as dependency on natural resources, reliance on long-lived fixed assets (e.g. transport, water and energy) and on extensive supply chains make a business or industry sector more sensitive to climate risks. [16] This can be split further into 'primary' sectors which involve acquiring raw materials, for example agriculture, forestry and extractive industries; 'secondary' sectors which capture manufacturing and assembly processes including utilities and construction; and 'tertiary' sectors which include commercial services such as retail, ICT, food and beverage and tourism.

However, as a comprehensive assessment of each and every sub-sector is practically impossible, most national climate risk assessments resort to an initial mapping exercise, often in consultation with stakeholders, to determine which sub-sectors to consider (e.g. based on how vulnerable the sectors are, or how important they are to national development). [27, 28, 29] While this is a logical approach it risks overlooking important interdependencies and relationships across sectors. [30] Importantly, even within one specific business sector, the risks and opportunities do not apply in equal measure to all companies involved as the business characteristics of different organisations (e.g. the disparate size between SMEs and large organisations) within a business sector may result in different climate change impacts. For example, recent advances in our understanding of adaptive capacity indicate that larger organisations have more resources for engaging in adaptation activities than smaller organisations, while SMEs tend to be less prepared and protected than their larger counterparts, often relying on ad-hoc measures to respond to natural disasters rather than adopting formal risk management processes. [31, 32, 33, 34, 35, 36, 37]

For a national climate risk assessment, it is difficult to capture those nuances, unless underpinned by specific analysis of business characteristics such as 'small versus large', or 'publicly listed versus privately owned'. For example, the climate risk assessment for

the United States conducted by the Risky Business Project [27] looks at the impact of climate change on business, but without considering the unique case of SMEs separately. Overall there is an information bias towards larger companies as they are more likely to record and share information about their own activities in reports or business publications, and therefore are more often subject to case study exercises than SMEs. [20]

Evidence base

Most of the relevant information on exposure and vulnerability of business and industry is not in the public domain. Large companies with sophisticated risk management functions have developed tools such as Enterprise Risk Management systems, which can capture these complex processes and may also consider climate risks alongside other business-related aspects, but smaller companies often lack any risk assessment process. When these company level risk assessments do exist, they tend to be owned by companies.

Some statutory (e.g. the Climate Change Act's Adaptation Reporting Powers) and voluntary disclosure regimes (e.g. Carbon Disclosure Project (CDP) reporting) do exist, and surveys have been conducted such as those from the Business Continuity Institute [38] or the Federation of Small Businesses [39] in the UK. In addition, some larger businesses do disclose climate change- and adaptation-related information as part of their standard corporate social responsibility and sustainability reporting processes. However, there are clear limitations to self-reporting in surveys and business reports. [20] While these do offer snapshots of risk perception and illustrate measures that companies are undertaking, they usually do not offer quantification or explicit identification of cause and effect.

This can also be the case in national climate risk assessments; for example, the National Climate Assessment for the United States assesses the capability of business and industry to continue operation despite climate change in purely qualitative terms. [40] Similarly, the UK Government Office for Science's approach to considering the impact of overseas climate change on the UK banking sector was qualitative, using impact pathways (i.e. a series of scenarios "...based on storylines of development in physical and social characteristics"). [41] A recent analysis from the European Environment Agency found that there is limited quantitative information about the vulnerability of, and risks faced by, businesses across Europe. [42]

Nevertheless, some examples of quantitative assessments exist, but these tend to focus on one specific sector or locality and require a significant amount of data and modelling capabilities. For example, Capon and Oakley [43] quantify the effect of extreme temperature on employees in the built environment sector. Their analysis considered the number of days per year when temperatures exceeded a 26°C threshold, suggesting approximately five million staff days were lost in 2010, which is 0.1% of available staff

time. Three million staff days are lost if a 28°C threshold is used instead, roughly 0.06% of available staff time.

Combining quantitative and qualitative evidence poses challenges for national climate risk assessments, particularly with regards to the weighing of evidence; 'Is a quantitative assessment of future impacts on sector x more informative or reliable than a qualitative process of using expert judgement and stakeholder feedback to identify risks?' An example of how this challenge can be addressed is the South Australia Integrated Vulnerability Assessment, which utilises quantitative assessments of potential productivity losses. [44] It also determines levels of adaptive capacity for each sector, based on discussions at workshops carried out in different regions. The vulnerability of each sector was then reassessed at regional level to produce regional adaptation plans, scoring exposure, sensitivity and adaptive capacity for each sector starting from the state-level information complemented by available literature and expert judgement. [45]

Adaptation responses

The above data challenges are particularly evident when capturing adaptation capacity and responses undertaken by companies. It is understood that many businesses are responding to climate risks by taking adaptive action, which might implicitly increase their resilience to climate change as well as influence the risks for others. [46] A range of case studies conclude that businesses and industry play an important role from building adaptive capacity within industries to delivering adaptation action at the regional and national levels. [47, 48, 49, 50, 51] These adaptation responses can also trigger significant economic activity. For example, a recent study suggests the UK adaptation economy (measured for adaptation and resilience (A&R) and for the sub set of A&R economic activities that can be directly related to climate change (A&RCC)) is the sixth largest in the world, with growth forecasts ranging from 3.7% to 7.1% per annum to 2020/21. [52] However, there is very little data available on the extent and effectiveness of these activities. [20] This is partly due to both confidentiality issues (e.g. concern with losses of commercial advantages) and a lack of any formal reporting processes. For instance, Climate-KIC [53] reports that a significant number of survey respondents believe that EU competition laws have limited industry's ability to collaborate and respond on climate change adaptation, leading to information being held back. Capturing this consistently in climate risk assessments is a challenge.

Furthermore, companies use a wide range of terms when describing their responses to climate risks, such as resilience, business continuity, enterprise risk management, or flood risk management. [47] Therefore many actions undertaken by businesses to improve their resilience or manage environmental or climate risks are not explicitly labelled as 'climate adaptation', making it difficult to identify them for a climate risk assessment. [20] Small companies are also less likely to take adaptive action; for example, large companies are more likely to consider current and future risks to their supply chains and distribution networks.

While many national climate risk assessments tend to recognize the importance of adaptation responses, this is usually captured through descriptive case studies. However, some studies do try to capture the role of adaptation responses more comprehensively; for example, see the 'Understanding and responding to climate change in the UK seafood industry' report which aims to provide a more comprehensive list of adaptation responses being taken both domestically and internationally. [54]

Scope

The climate change risks and opportunities for business and industry are multi-layered and influenced by factors related to location as well as international dimensions such as trade routes and geopolitical stability in affected regions, exposure to fluctuations in market prices of commodities such as oil (as occurred after Hurricane Katrina), and changes in demand for the businesses' goods and services. [22, 55] National risk assessments vary in their treatment of these international aspects, as the comparison between UKCCRA1 and 2 below shows. For example, the Brazil National Adaptation Plan to Climate Change says little about the interdependencies associated with impacts of climate change overseas. [28] Sectoral risk assessments also differ; for example, whilst the 'A Changing Climate for Cider' report focused on the national aspects of climate change for the UK cider industry, the 'Understanding and responding to climate change in the UK seafood industry' report considers international dimensions. [54, 56]

In addition to the domestic/international perspective it also matters what type of impacts are considered. Traditionally, most emphasis of risk assessment has been on direct and quantifiable risks, such as property damage in the wake of a flood. [57, 58] However, flooding does also disrupt transport routes and infrastructure, affecting supply routes and potentially altering demand for certain products. [59, 60] These indirect impacts are particularly hard to estimate as they largely occur outside a businesses' own facilities and potentially out of scope of their own adaptation measures. Importantly, these indirect impacts can often be more significant than the direct impacts, as highlighted by a survey of flood-affected businesses in Sheffield and Wakefield in the UK. [8] Disruptions to supply and distribution chains is one of the more important of these impacts, but linking it to the revenue or share price of a company or a sector remains very indicative rather than exact. For example, it has been reported that share prices can fall by between 7% and 30% on average following failures in supply chains relative to benchmark companies. [57] Overall, there is very little work that looks at this problem comprehensively.

Over the last decade a range of tools have emerged that allow a broader scope when assessing climate risks by combining knowledge and technical skill from disaster risk management and catastrophe modelling and applying this in the context of climate risks. [61] Nevertheless, capturing direct and indirect impacts, as well as more intangible risks such as customer trust or reputation, poses a challenge for any national climate risk assessment. While there may be advances in a particular area such as the insurance

industries' modelling [62] there are significant barriers to applying these across sectors. This was one of the findings of the 'Understanding and responding to climate change in the UK seafood industry' report, which highlights the need to improve modelling of extreme events suitable for use within the industry. [54] Considering the interplay between national-level risk assessment methodologies and those tools used by industry is important, but often overlooked. Closer collaboration between government and businesses could help establish where the synergies and boundaries between national-level assessment and company or sector-analysis are, and how one can help inform the other.

Interdependencies

Climate risks and opportunities for businesses are also influenced by a range of interdependencies, for example between different industries, between businesses and infrastructure, between climate and resource availability, and between business operations and socio-economic processes. [22, 30] Clustering around business centres, sharing the same resources and depending on services and goods from near and far all contribute to a complex web of interactions and relationships. This can create multiple pressure points and lead to cascading impacts. For example, co-located companies (such as in hubs or business parks) all rely on the same infrastructure and are consequently exposed to greater risks should that infrastructure suffer flooding. This dynamic gained some recognition after the Thai Floods in 2011. The flooding caused \$45bn total damage, with 9,859 factories forced to close due to the direct impacts of the flooding. [63] However, the interdependencies were far reaching; the flooding resulted in Don Mueang Airport being closed for six months, causing significant travel disruption. Furthermore, disruption to hard drive manufacturing, which Thailand accounted for 45% of globally, resulted in the global hard drive price doubling. [63] The complexity of the interdependencies associated with different climate impacts for businesses and industries are starting to be recognized, but have been largely ignored in terms of specific research. [30]

Public policy

There is an increasing awareness that private sector adaptation requires an enabling regulatory environment and as well as support measures (for example, see Werners et al. [64]) to ensure the private sector is (i) sufficiently informed of climate risks, (ii) incentivised to invest in adaptation measures, and (iii) not stifled by restrictive government policy. [48] For example, a majority of businesses surveyed by the UN Global Compact and UN Environment Programme for a 2012 report acknowledged the importance of public policy. [65] However, the effects of public policies on climate change adaptation can differ: "some policies will have direct impacts on the ability of businesses to adapt to climate change; others will influence it indirectly". [66] In the latter case, more public policy requiring or encouraging businesses to report on their climate risk and adaptation actions may prove useful. In general, risk assessments have acknowledged the importance of policy to promoting adaptation, but do not appear to have specific methodologies for incorporating it into their assessment. All the examples

reviewed (see Appendix 1) reference regulation and public policies as determinants of company behaviour – see, for example, the Indonesia Climate Change Sectoral Roadmap, which notes the role of government policy. [67]

Similarly, the climate risk assessment for the United States conducted by the Risky Business Project acknowledges that “...the economy runs most smoothly when government sets a consistent policy and a regulatory framework within which business has the freedom to operate. Right now, cities and businesses are scrambling to adapt to a changing climate without sufficient federal government support, resulting in a virtual “unfunded mandate by omission” to deal with climate at the local level”. [27] However, there is no indication of an assessment of the impact of regulation and public policies on risk levels and company behaviour.

In summary, we identify six aspects that are important when including risks to business and industry in national climate change risk assessments (Table 1).

Table 1: Business and industry related aspects for climate change risk assessments

Business and industry related aspects for climate change risk assessments
Scale of assessment: sectoral focus most common, requires selection of sectors; treatment of different business characteristics (e.g. size) within a sector remains unclear
Evidence base: limited quantitative evidence, many risk assessments consider both qualitative and quantitative, but difficulty in combining them; company surveys and reports important source of evidence; challenge of commercial sensitivity of data; need to engage with business and industry to receive input
Adaptation responses: advances in understanding of adaptive capacity, but very limited evidence on nature of adaptation action and effectiveness of measures
Scope of impacts: direct and indirect risks acknowledged, but indirect risks complex; international dimension very important for many businesses and industries
Interdependencies: recognition of linkages across companies, sectors, business activities (e.g. transport links) is emerging, but no clear methodology to capture in risk assessments
Public policy: role of public policy and regulation as determinants of business decisions acknowledged, but not assessed

(Source: authors)

While selection of scale and treatment of evidence are practical questions, the remaining four aspects relate to more fundamental questions of identifying and

incorporating the complexities of business processes and vulnerabilities into a national climate change risk assessment. We now investigate in greater detail how the UKCCRA process approached those methodological challenges (sections 3 and 4).

3. Assessing business and industry risks for the UKCCRA process

The UKCCRA process is particularly useful as an exemplar due to the methodological changes that occurred between UKCCRA1 and UKCCRA2 (see Appendix 2 for a more detailed overview). This was the result of lessons learned from the first assessment, new evidence becoming available and a reduced budget, limiting the amount of newly commissioned research significantly. A particular change was the revised remit, explicitly asking the risk assessment to consider adaptation action as well as international aspects and indirect impacts relevant to the UK – see figure 1 below. It is worth highlighting that one of the goals of UKCCRA1 was to use a consistent methodology to assess risks across a range of areas, including business. This meant that the methodological choices were shaped by the need to be applicable to a broader scale of application including water and biodiversity for example. The approach used in UKCCRA2 of adopting a business function approach allowed a different perspective to be gained and provided more flexibility in adapting the methodologies to the needs of different types of business activities across sectors. This enabled extending the risk assessment to address issues not considered in UKCCRA1 including adaptation action, public policy, international aspects and indirect impacts relevant to the UK – see Figure 1 below. In UKCCRA2, the focus on business allowed the development of a new broader approach to analyse risks based on six key business functions, which allowed a clearer recognition of the interdependencies that exist between climate risks and business systems and processes.

The terms ‘business and industry’ are not specifically defined in both assessments – suggesting a rather pragmatic and broad conceptualization as the ‘private sector’ side of the UK economy, which would include domestic as well as foreign companies operating in the UK. While UKCCRA1 has the boundary of the UK territory, UKCCRA2 specifically includes the international elements of UK businesses’ distribution and supply chains.

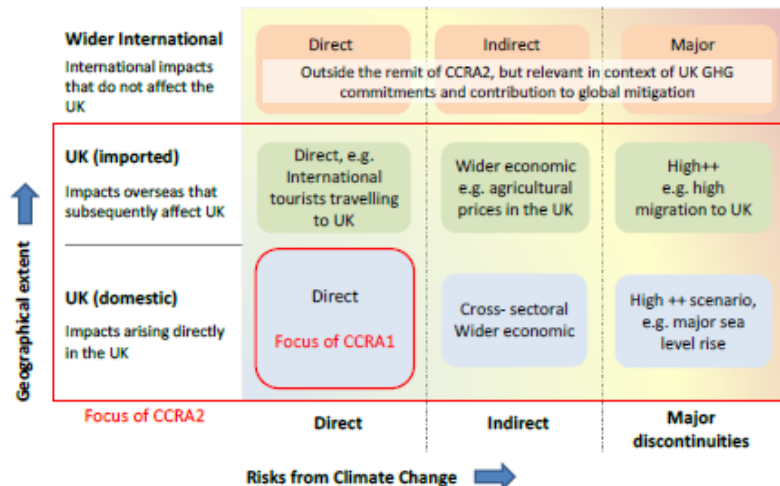


Figure 1 – Focus of UKCCRA2 (source: Warren et al. [14], adapted from UKCCRA1)

The results from UKCCRA1 as they relate to business and industry are summarized in Appendix 3, and the results of UKCCRA2 are summarized in Appendix 4.

Overall, both risk assessments indicate fairly similar types of risks. But while UKCCRA1 pursues a process of analysing and ranking specific sectoral aspects, UKCCRA2 provides a broader overview, synthesizing the current knowledge about how climate risks and opportunities affect six core business functions. Those six business functions are ‘products and services, employees and labour productivity, site location, distribution (output), supply chain (input), and access to capital’. This ‘business function’ approach was first used by the UK Climate Impact Programme to enable companies to conduct their own risk assessment as a ‘business areas climate assessment tool’ (BACLIAT). [68] For each of these functions, UKCCRA2 considers current and future risks and opportunities arising from climatic changes (see Figure 2 below).

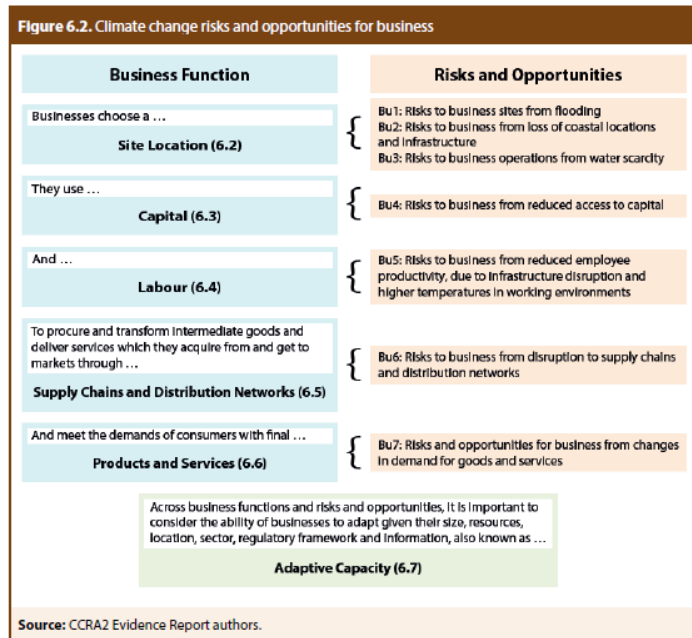


Figure 2 – Risks and Opportunities (source: Surminski et al. [11])

The methodological evolution of the UKCCRAs needs to be seen in the light of the underpinning remit of the assessment: the UKCCRA process is directly embedded in the UK policy framework set up by the Climate Change Act 2008. According to the Act, the UK government has to update the National Adaptation Programme (NAP) by developing policies and proposals that address the risks identified in the UKCCRA. As such the main audience for the UKCCRA remains the UK government alongside the Devolved Administrations, and the information provided in the assessment needs to be presented in a way that facilitates the identification of policy and proposals for the NAP. This policy focus was reinforced for UKCCRA2 as it was tasked to give recommendations on what government action to take considering the existing knowledge about current and future risks, opportunities and responses by business and industries. UKCCRA 2 notes that the existing evidence base suggests with high confidence that flooding, water scarcity and international climate impacts are the key current and future climate risks for UK businesses, while for other climate risks the picture is less clear.

The key findings from both risk assessments therefore differ in extent and presentation—as outlined below in table 2:

Table 2: Key findings from UKCCRA1 and UKCCRA2

UKCCRA1	UKCCRA2
Reduced returns for UK financial institutions' investments due to the absence of mainstreaming climate risk and adaptation into decision-making processes (BU1) – too uncertain to assess.	Risks to business sites from flooding (BU1) – more action needed (research priority in Northern Ireland, Scotland and Wales)
An increase in monetary losses as a result of an increasing proportion of UK tourist assets (natural and built) at risk from flooding (BU2) – high consequences in the future with medium confidence.	Risks to business from loss of coastal locations and infrastructure (BU2) – research priority
A decrease in water (groundwater and surface water) availability for industrial usage (BU3) – high consequences in the future with low confidence.	Risks to business operations from water scarcity (BU3) – sustain current action
An increase in monetary losses as a result of interruption to business from flooding (BU4) – negative consequences in medium- to long-term future with medium confidence.	Risks to business from reduced access to capital (BU4) – watching brief
A decrease in productivity and revenues due to ICT loss or disruption (BU5) from extreme climate events – too uncertain to assess.	Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments (BU5) – research priority
Increased exposure for mortgage lenders (BU6) – medium consequences in the near and long-term future with low confidence.	Risks to business from disruptions to supply chains and distribution networks (BU6) – sustain current action
An increase in insurance industry exposure due to flooding (BU7) – high consequences in the near and long-term future with medium confidence.	Risks and opportunities to business from changes in demand for goods and services (BU7) – watching brief
An expansion of new or existing tourist destinations in the UK (BU8) – opportunities for growth in the long-term with low consequence.	
A decrease in output for UK businesses due to an increase in supply chain disruption as a result of extreme events (BU9) – too uncertain to assess.	
Loss of staff hours due to high internal building temperatures (BU10) – medium near- and long-term consequences with medium confidence.	
Reduced returns for UK financial institutions' investments due to the absence of mainstreaming climate risk and adaptation into decision-making processes (BU11) – too uncertain to assess.	

Source: UKCCRA1 and UKCCRA2

4. Discussion of the UKCCRA experience and pointers for future national climate risk assessment

This section reflects on the methodological changes that occurred between UKCCRA1 and UKCCRA2 with regards to the assessment of climate change risks to business and industry. In general terms, UKCCRA1's approach to assessing risks to business and industry follows a more traditional assessment approach, with systematic evaluation of risks for particular sectors. UKCCRA2 instead is a stock-take, an assessment of the current knowledge about risks, with the aim of identifying what type of government action should be pursued in response. As such UKCCRA2 was tasked to expand the scope of the risk assessment by including evidence on a wide range of risk drivers, including international aspects, role of adaptation and public policy and socio-economic aspects. Table 3 shows how both risk assessments are responding to the six criteria outlined in Section 2.

Table 3: Comparison of UKCCRA 1 and UKCCRA2 in relation to six business specific assessment criteria

Business specific criteria	UKCCRA1	UKCCRA2
Scale of assessment	<p>Sectoral – identifying and assessing financial services; tourism; food and beverage manufacturing; oil, gas and mining; and chemical manufacturing.</p> <p>SMEs identified as low adaptive capacity</p>	<p>Business Function Approach: products and services, employees and labour productivity, site location, distribution (output), supply chain (input), and access to capital.</p> <p>Business characteristics highlighted as a challenge, specific reflection on SMEs</p>
Evidence base	<p>Lit review plus specific analysis and development of risk metrics focused on future risks.</p> <p>Supported through stakeholder engagement (workshops and consultation, ongoing engagement with project steering group, in-house experts and Adaptation Sub-Committee)</p>	<p>Lit review, capturing broad range (peer reviewed, sectoral, surveys, interaction with business sector throughout the process), considering current and future risks.</p> <p>Expert judgement as key factor in urgency scoring and prioritizing risks.</p> <p>No new quantitative assessment for business and industry risks conducted.</p> <p>Supported through stakeholder events around the UK, expert workshops calls for evidence, two stakeholder reviews</p>
Adaptation	Not considered	Assessment criteria – qualitative

Responses		analysis
Scope of impacts	Direct and indirect, only domestic risks,	Direct and indirect, international and domestic risks (with international also covered in Chapter 7 of UKCCRA2 [69])
Interdependencies	Mentioned, but not considered in detail	Several risks identified, also further considered in chapters 4 [70] and 8 [71]
Public policy	Not considered	Assessment criteria – qualitative, includes list of relevant policies and describes possible impact

(Source: Authors)

Importantly, the evolution from UKCCRA1 to UKCCRA2 was shaped by pragmatic needs as well as conscious methodological choices. A particular motivation was the need to broaden the focus of the assessment. However, UKCCRA2 was also constrained to look at existing evidence rather than conducting new analysis, mainly driven by the far smaller financial budget (UK£ 650k for UKCCRA2 versus £3m for UKCCRA1). The quality of UKCCRA2 is therefore driven by the underlying evidence, in particular by any new studies that emerged after UKCCRA1. Equally important is the lens through which this evidence is being investigated. This makes the UKCCRA process a methodologically interesting example. Below we discuss some of the key aspects that emerge from the UKCCRA experience.

- **The business function approach provides a useful new assessment lens for national level risk assessment.**

Adopting the business function approach in UKCCRA2 allowed literature to be looked at through a different lens, not limiting the evidence collection to certain pre-selected business and industry sectors. At first look this casts the net much wider, reducing the danger of ignoring important insights from sectors generally not deemed to be a priority, while also avoiding a possible false sense of security for government and those sectors not investigated. The business function approach can also help to capture the nuances of climate risk and adaptation for individual businesses in relation to their specific activities and business characteristics such as size, recognizing that businesses within particular sectors or industries will not be uniformly affected by climate change; instead, much will depend on the unique nature of their business functions such as their location, supply chains, and access to capital. As such, the business function approach offers a more pragmatic understanding of how business and industry fits into the overall economy, by identifying risks and opportunities “...across different business types, different economic sectors and industry sub-sectors, as well as across regions”. [22] For example, UKCCRA2 acknowledges that businesses located in coastal areas face additional climate risks from coastal flooding. [22] Similarly, it concludes that capital could become more expensive in the future for businesses who do not take adaptation action regardless of industry. [22] With regards to business size, a number of surveys conducted in recent years were available for UKCCRA2 to draw upon that were not

available when UKCCRA1 was prepared (e.g. AXA and UNEP [72]). For example, UKCCRA2 highlights that small businesses are less likely to take steps to ensure that their supply chains are resilient to climate change, and adopt different attitudes to extreme weather events when compared with their larger counterparts. [22] Furthermore, it notes that the low adaptive capacity of SMEs is a key issue that requires further attention.

Importantly, the business function approach is based on the understanding that climate impacts on business and industry are multi-faceted and relate to key business decisions – such as where to locate operations, what products to offer, and how to secure access to capital. These are not taken in isolation but are driven by a range of factors such as market conditions and growth prospects. Understanding these decision processes is necessary to identify barriers to adaptive behaviour. The business function allows a broader reflection on capacity and adaptation action as it is not constrained by a sectoral perspective. For example, chapter 6 of UKCCRA2 gives a strong degree of attention to how general risk management processes, such as business continuity planning (BCP), are being adopted by businesses. In particular, it notes that the adoption of BCP remains relatively low for SMEs, and slightly higher for larger corporations. Furthermore, it notes that studies suggest a low percentage of SMEs possess business interruption cover (recalling that chapter 6 of UKCCRA2 analyses existing evidence rather than conducting new studies). [22] These are general lessons which transcend business sectors, and therefore have more universal applicability and offer more ‘entry points’ to individual businesses interested in the findings. The ‘business function’ also provides a useful lens to investigate the international aspects of climate change. For example, the recognition of supply chains and distribution networks as a key business function allowed for the vulnerability of international supply chains to climate change to be highlighted as a key risk that transcends business sectors. [22]

However, this does not mean that a sector-by-sector approach does not provide valuable insights into risks and adaptation action. Indeed, UKCCRA2 acknowledges that certain industries are more likely to be impacted by climate risks and opportunities (e.g. tourism). As such, sector-by-sector analysis provides a level of detail that the business function approach cannot; for example, by looking closer at the particulars of BCPs being adopted in different sectors, or by providing greater insight into adaptation action being taken in highly specialised industries (e.g. the pharmaceuticals industry). One could therefore argue that these more detailed sectoral assessments provide the backdrop to the broader national level analysis, but that they alone do not suffice to capture the complexities of climate change risks to business and industry. As such, business function and sectoral approaches are required in tandem.

- **The evidence base is growing, but its diversity and variety poses a challenge to a systematic assessment.**

Between UKCCRA1 and UKCCRA2 the evidence base for climate change risks to business and industry has increased in number and advanced in detail. Appendix 5 contains a list

of the key new reports released in this period. This development is partly a direct response to the shortcomings of UKCCRA1. One obvious area where evidence has been increasing is in the context of international risks: UKCCRA2 set out specifically to include international aspects, which had been excluded from UKCCRA1. This expansion of the scope led to a greater reflection on the impacts of climate change on international supply chains (particularly in relation to the supply of food, clothing and electronic equipment), [22] supported by recent studies on issues such as the impacts of climate change on international food production and the flow-on effect on markets, trade and domestic prices locally). [71] Similarly, UKCCRA2 also recognized new evidence that climate change could give rise to international business opportunities; for example, in adaptation products such as biotech. [69]

The expanded evidence base is also the result of closer engagement of business and industry representatives in the UKCCRA process post UKCCRA1. This included specific calls for evidence, which were sent to mayors, business associations and trade bodies, and which secured additional material for UKCCRA2. [22] However, as is typical in the context of business and industry risk, capturing this diverse set of official reports, surveys, and case studies that emerged also creates a challenge: most of these reports considered different climate scenarios, some included estimates of adaptation action, and others did not. While not surprising, given the wide range of literature considered, this is a challenge in terms of comparison, ranking and tracking trends. This became particularly apparent in the context of socio-economic drivers. As part of UKCCRA2, the authors were asked 'which socio-economic factors could influence the risk/opportunity in future and then consider how changes in these could affect the magnitude of the risk'. UKCCRA1 did not have such an explicit focus on these issues. While this can be considered as an important advance of the methodology, the conclusions remain fairly limited other than general acknowledgements that economic growth and population trends remain the overarching determinants of business risk and opportunity. For example, it is noted that climate change will impact the UK's tourism industry, but demand is 'likely to be dominated by wider socio-economic trends such as household disposable income and currency exchange rates'. [73] What remains unclear is how these risk drivers interact and potentially reinforce each other.

- **Understanding interdependencies, adaptation responses, and role of public policy is crucial to improving adaptive capacity, but major research gaps exist.** UKCCRA2 demonstrates that there is a growing recognition of the importance of interdependencies and cascading impacts when looking at risks for business and industry. When climate risks interact with business systems and processes, there is the potential for cascading effects. For example, it notes that businesses can influence the adaptation action of others due to the interdependencies between them (e.g. the impacts different businesses can have on resource availability such as water) or along supply-chains. [22] Furthermore, co-located or clustered businesses may all be reliant on the same infrastructure and transport routes. [22] Another example highlighted in UKCCRA2 is the risk of insurance companies leaving markets due to the high risk

associated with climate change, which would also have follow-on effects for other businesses. Understanding these interdependencies is crucial to improving the adaptive capacity of businesses; without knowledge of the risks, adaptive action cannot be taken. Furthermore, UKCCRA2 notes that more efforts should be made to incorporate such interdependencies into joint risk management plans (e.g. relating to flooding). To this end, it recognises that further research is needed on the interdependencies that exist between climatic events or gradual changes, broader risk drivers, infrastructure performance, business activities, regulation or public policy. [22]

UKCCRA2's focus on adaptation also meant that greater focus was placed on the importance of public policy, which was not considered in UKCCRA1 [25]. Public policies are outlined for each business function at the beginning of the section, and a list of key policies is provided. However, if and how these are having an impact remains unclear.

What follows from this is an important insight: that further investigation is needed on how policy and regulatory measures can influence the ability of businesses and industry to take adaptation action, and a better understanding of why governments choose to adopt particular measures. These adaptation actions can range from relatively 'soft' measures that are designed to spur action from other stakeholders (e.g. promoting disaster risk insurance that businesses can then access to minimise their risk of loss), and 'hard' measures that directly involve government incentivising adaptation (e.g. lending programs targeted at promoting adaptation and public investment in infrastructure and programmes). Different measures may also be targeted at different stages of the adaptation cycle (e.g. the decision to adapt, the timing of adaptation action, and the effectiveness of the measures adopted). Understanding these dynamics more fully is particularly important when considering the interdependencies between government action, socio-economic trends and individual business decision-making.

- **UKCCRA2 provides the government with explicit guidance on public policy with regards to climate change and business and industry.**

UKCCRA2 was tasked with providing explicit guidance to the UK government on what action to take in response to climate change risks. As shown in Table 2 above, this was provided according to urgency scores – see also Appendix 4. The only risk identified as 'more action needed' is flood risk to businesses in England. This mainly reflects on the strong evidence base on flood risk and the projected rises in risk.

However, identifying risks to industry and other business sectors requiring urgent government action implies identifying the sphere of influence of the government within the private sector. This is not without challenge and the boundaries between autonomous adaptation and need for policy and regulatory guidance are often unclear. In the UK, government has a direct impact on regulated businesses such as electricity, water and transport. These sectors have the duty to report on their own climate change risks when requested by the government. For unregulated sectors, according to the NAP, the main role of government is to enable and promote climate change adaptation

by raising awareness and understanding about climate change risks, encourage business to actively consider these risks, and undertake research to increase the understanding of climate change impacts on growth and the economy. [74] UKCCRA2 also discusses the role of government intervention and notes that in addition to the action areas identified the government has a role to play in information sharing and raising awareness, to enable businesses to better understand their risks. [22] It also notes that there may be a case for public policy to address barriers to growth in adaptation markets, but states that the relationship between private adaptation action and public policy remains unclear [22]. Indeed, any policies to support businesses and consumers can have unintended consequences that might be more difficult to assess. Government actions that focus on the short term may also inhibit corporate actions or investments to avoid potential losses in the future. For example, in the UK the flood insurance market is subsidised by the government, which could in practice reduce the incentives for householders and insurers to encourage behaviours that reduce the risk. [75] Whether these recommendations receive any traction will not be clear until the release of the next NAP.

5. Conclusion and outlook

In this paper, we have identified a range of aspects that are important to understanding climate risks to businesses and industries when conducting national level climate change risk assessments. They include the scale of the assessment, the evidence base, accounting for adaptation responses, defining the scope of impacts considered, and the role of public policy and regulation. We explored these aspects in the context of the shift in aim, methodological approach and findings from UKCCRA1 to UKCCRA2 to a broader, less sectoral-specific stocktake of the current understanding of risks to business and industry. The business-function lens used in UKCCRA2 appears well suited to capture the complexities of hazards, vulnerabilities and exposure in relation to business and industries, as it offers a view on processes and flows across different types of businesses and industries. The business function approach also reveals a clear lack of systematic assessment of those aspects, with UKCCRA2 arguing that the lack of awareness and understanding of how these complex processes can impact a particular business poses clear risks. [22] In addition, UKCCRA2 acknowledges that the costs and benefits of specific adaptation action tend not to be incorporated into risk assessments but can have significant implications for adaptation decisions and future risk levels.

From the above discussion, it is clear that the approach taken in UKCCRA2, particular due to its broader remit and the availability of additional studies to draw upon, provided a more holistic understanding of climate risks to businesses and industries in general, whilst the sectoral approach taken in UKCCRA1 captured a level of detail that is not possible with the business function approach. This suggests that applying both approaches in tandem might be the most suitable avenue for future risk assessments.

However, there are still areas where we do not have a clear picture of the effectiveness of the different approaches taken in UKCCRA1 and UKCCRA2.

Firstly, drawing direct comparisons between the approaches taken in UKCCRA1 and UKCCRA2, and identifying which approach is more effective, is difficult. This is because of the more limited remit of UKCCRA1, which did not take into include adaptation behaviour, the role of public policy, as well as international aspects and interdependencies across risks and different types of business activities. It may be the case that the sectoral approach taken in UKCCRA1 could more effectively capture these dynamics for individual sectors.

Secondly, the evidence base is still limited in some areas. Greater disclosure from businesses (both SMEs and medium to large companies) is needed in order to develop a better understanding of which adaptation measures work, and why. This makes it difficult to draw a direct comparison between the approaches taken in UKCCRA1 and UKCCRA2. Further investigation is also needed on how policy and regulatory measures can influence the ability of businesses and industry to take adaptation action, and a better understanding of why governments choose to adopt particular measures. How these factors are affected by, for example, the interdependencies between policy, socio-economic trends and individual business decision-making is also unclear. This should be a major research priority going forward if policy measures adopted to promote adaptation by business and industry are going to be fully informed.

Ultimately, and perhaps most importantly, reviewing the methodological differences between UKCCRA1 and UKCCRA2 highlights a number of areas that should guide the next phase of research for UKCCRA3 and other national risk assessment processes:

UKCCRA2 underlines the importance of understanding behavioural aspects and interdependencies as well as the influence of policy and regulations, and acknowledges the difficulties in capturing them. The behaviour of individuals, businesses and government entities before, during and right after a natural disaster can dramatically affect future impacts and recovery time. Human behaviour and risk perception are difficult to quantify and unpredictable in nature, and therefore remain a complex subject for quantitative risk scientists to understand and integrate into their methods. While this assertion may initially raise more questions than it answers this is an important step forward in the evolution of climate change risk assessments.

UKCCRA2 also shows the need for more underpinning research and analysis in an interdisciplinary way, especially with regards to social sciences and the experience gained from studies of vulnerability and behaviour. In particular, disaster risk and natural hazards science provides an important foundation for analysing climate extremes such as floods and storms, including the assessment of their impacts for business and industry (see for example Tierney [76], Aerts et. al. [77], and [78]). However, many of the advances made consider firm-level, local or regional assessments, and tend to focus

on one particular hazard. Translating this into a multi-hazard national climate change risk assessment of business and industry remains complex. Here UKCCRA2 appears to have achieved its given remit and provided guidance to the UK government with regards to public policy measures. Specifically, UKCCRA2 identifies three research priorities for government:

- Risks to business from loss of coastal locations and infrastructure - more research needed on costs and benefits of adaptation options for different coastal areas;
- Risks to business from reduced employee productivity - more research needed on disruption to infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity; and
- The risk of flooding to business sites is a research priority in Northern Ireland, Scotland and Wales.

UKCCRA2's stakeholder engagement process indicated appetite for using the evidence reports to support company decisions. Importantly, sectoral approaches have limited appeal beyond those operating in or dealing with those sectors. The business function approach is therefore more likely to provide an easier entry-point to a wide range of businesses to consider their risks, opportunities and responses. However, a certain 'translation' or refinement of the findings would be needed to make them applicable to business decision-making.

Finally, in the run-up to UKCCRA3 and for other national climate change risk assessments, there is the need to increase data sharing between stakeholders. While the business engagement process of UKCCRA2 increased the degree of involvement of stakeholders, there is still a lack of data sharing between business and government, and across different branches of government. [22] Although commercial confidentiality and data protection are important factors, there is a strong case for better access to and use of existing data and modelling capabilities developed in one sector or within one part of government.

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Appendix 1 – Examples of National-level Climate Change Risk Assessments of risks to business and industries

Country	Name of risk assessment	Scope: Sectoral or else?	Approach: Quantification or qualitative?	Considers adaptation action in the analysis ?	Type of impacts considered: direct/indirect, national, international, interconnectedness?
Australia	‘Australasia’ (contributions to IPCC 5 th Assessment Report) 2014 [79]	Multi-sectoral and regional	Both	Yes	All of the above considered.
Brazil	National Adaptation Plan to Climate Change 2016 [28]	Multi-sectoral	Many initiatives focus on improving quantitative data	Yes	Nationally focused, looks at direct and indirect impacts.
Europe	Climate change, impacts and vulnerability in Europe 2016 [42]	Yes but predominant regional focus	Some quantitative data (e.g. on tourism)	Yes but predominant regional focus	Regional focus, direct and indirect impacts considered, interconnectedness considered.
Indonesia	Indonesia Climate Change Sectoral Roadmap ICCSR [67]	Multi-sectoral	Both	Yes	National, focus on direct impacts but indirect also considered.
South Australia	Central Local Government Region Integrated Change Vulnerability Assessment - 2030 [44]	Multi-sectoral	Quantitative	Yes	Regional focus, direct and indirect impacts considered, interconnectedness considered (e.g. trade).
Sri Lanka	National Adaptation	Multi-sectoral	Qualitative	Yes	National focused,

	Plan for Climate Change Impacts in Sri Lanka 2016-2025 [29]				looks at direct and indirect impacts.
UK	A Changing Climate for Cider – November 2008 [56]	Sectoral – Cider Industry	Qualitative	Yes	Industry and national focused, considers direct and indirect impacts.
UK	Understanding and responding to climate change in the UK seafood industry (2015) [54]	Sectoral – Seafood Industry	Both - adaptation discussion qualitative	Yes	Sector focused, considers direct and indirect impacts, international dimensions included.
UK	International Dimensions of Climate Change – The Impact of Climate Change Overseas on the UK Financial Services Sector (2010) [41]	Sectoral – Financial Services Sector	Qualitative	Yes	Sector focused, international dimensions the focus, direct and indirect exposure considered.
UK	The impact of climate change on the UK insurance sector (2015) [62]	Sectoral – Insurance Sector	Both	Yes but limited	Sector focused, direct and indirect impacts considered, international interconnectedness considered.
UK	UKCCRA1 [21]	Sectoral	Both	Limited	National, direct and indirect impacts, interconnectedness considered.
UK	UKCCRA2 [22]	Business function approach	Both	Yes	National and international, direct

					and indirect impacts, interconnectedness considered.
UK	Climate change and its effects on small businesses in the UK (2006) [80]	Small business focused	Quantitative – survey based	Referred to but no discussion	Report focused on AXA survey results, minor discussion of impacts, international aspects.
USA	National Climate Assessment (2014) [40]	Multi-sectoral and regional	Both, but mostly qualitative	Yes	Direct and indirect impacts considered, international linkages considered.
USA	A Climate Risk Assessment for the United States (2014) [27]	Multi-sectoral and regional	Both	Yes but focus on risk	National focused, direct and indirect impacts considered little international discussion.

Source: Authors

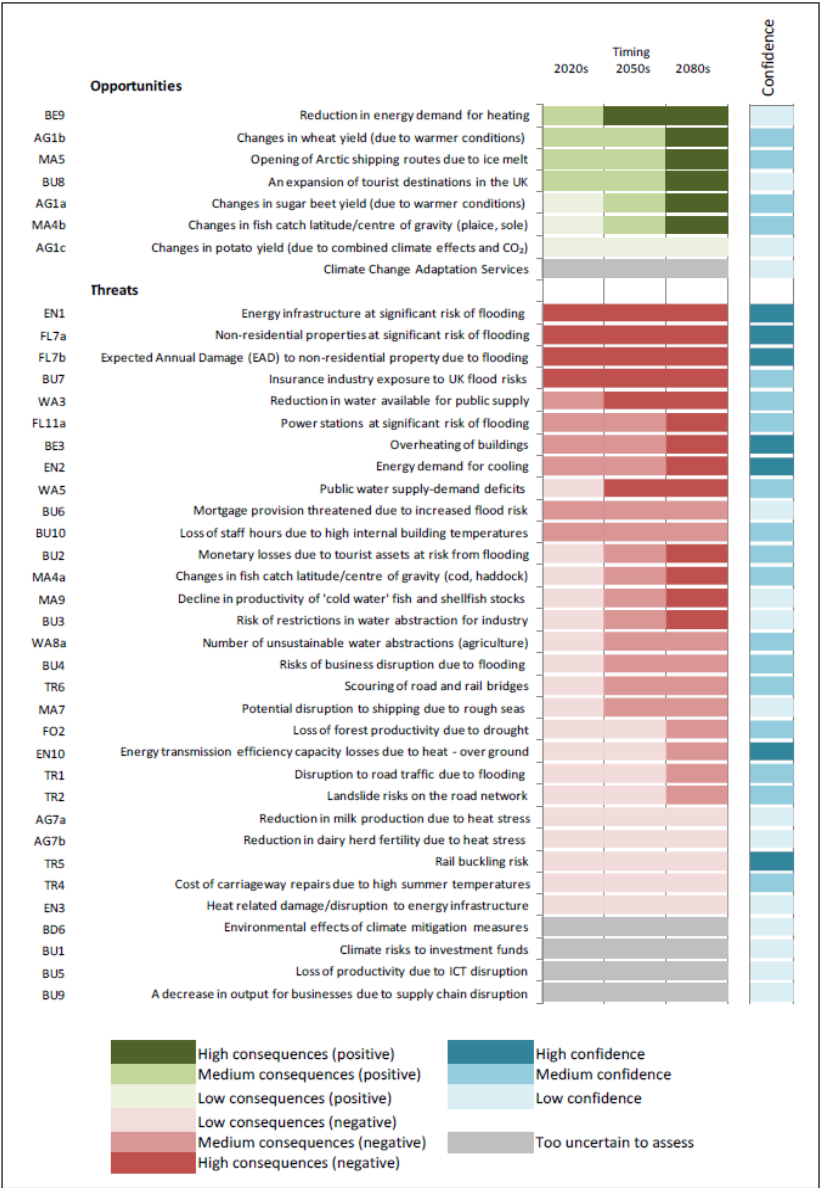
Appendix 2 – Differences in approach between UKCCRA1 and UKCCRA2

Table 1.2. Differences in approach between the CCRA1 and CCRA2 Evidence Reports		
Aspect of report	CCRA1 Evidence Report	CCRA2 Evidence Report
Coverage of risks and opportunities	100+ risks and opportunities, prioritised from a list of 700	Around 60 risks and opportunities, chosen by Government and the report authors
Metric for summarising the results	Focused on magnitude	Focused on urgency
Time periods covered	2020s, 2050s and 2080s	Current, 2020s 2050s and 2080s, post-2100 for sea-level rise
Type of analysis	Mix of existing data and new analysis to create 'response functions' for risks and opportunities	Mostly synthesis of existing analysis with some new data from four specially-commissioned research projects
Use of climate science	Used the UK Climate Projections, UKCP09, to explore different climate scenarios	Literature used to inform the Evidence Report is based on a mixture of studies that use UKCP09, the global CMIP5 model ensemble, single models and other scenario-based approaches
Consideration of drivers of risk	Results did not include effects of planned adaptation or socio-economic change (beyond population growth)	Results include analysis of the effects of adaptation and socio-economic change on risk/opportunity, where evidence exists
Spatial coverage	Covered England, Northern Ireland, Scotland and Wales. Did not quantify international risks	Covers England, Northern Ireland, Scotland and Wales. Includes a chapter on international dimensions
Products	11 sector reports, one synthesis report, three national summaries (~2,000 pages)	One synthesis report plus an Evidence Report of eight chapters, four national summaries, four research reports (~2,000 pages)
Authors	Authored by consultants led by HR Wallingford, signed off by Defra	Authored by independent academics and consultants led by the ASC, signed off by the ASC
Cost	£3 million over three years	£650K over three years
Funders	Defra, devolved administrations	Defra, devolved administrations, Natural Environment Research Council, Environment Agency

Source: Chapter 1, UKCCRA2 [81]

Appendix 3 - Results of UKCCRA1

Figure 5.1 Summary of business impacts with an indication of direction, magnitude and confidence



Source: UKCCRA1 evidence report [21]

Appendix 4 – Results of UKCCRA2

Table SR.A4: Urgency of additional action to support business		
Risk/opportunity	Urgency score	Rationale for scoring
Bu1: Risks to business sites from flooding (6.2.2, 6.2.3)	More action needed (research priority in Northern Ireland, Scotland & Wales)	More effort is needed in England to address flood risks and inform businesses of their current and future exposure and what steps they might take to limit impacts. More research needed elsewhere in the UK to understand uptake of flood protection measures by businesses and how spending plans on defences and other measures may or may not protect individual businesses.
Bu2: Risks to business from loss of coastal locations and infrastructure (6.2.2, 6.2.3)	Research priority	More research needed on costs and benefits of adaptation options for different coastal areas.
Bu3: Risks to business operations from water scarcity (6.2.4, 6.2.5) NB: Also see related infrastructure risk In9.	Sustain current action	Sustain current actions to create more flexible abstraction regimes and promote water efficiency among businesses.
Bu4: Risks to business from reduced access to capital (6.3)	Watching brief	Monitor and research action by regulators, banks and insurance firms, and information disclosures by UK companies.
Bu5: Risks to business from reduced employee productivity, due to infrastructure disruption and higher temperatures in working environments (6.4.2, 6.4.3, 6.4.4, 6.4.5)	Research priority	More research needed on disruption to ICT, power and transport infrastructure which prevents workers accessing premises or working remotely, and on impacts of higher temperatures on employee safety and productivity.
Bu6: Risks to business from disruption to supply chains and distribution networks (6.5) NB: Also see related international risks It1 and It3.	Sustain current action	Sustain and monitor the uptake of existing guidance which helps businesses improve the resilience of supply chains and distribution networks, particularly at the international level.
Bu7: Risks and opportunities for business from changes in demand for goods and services (6.6)	Watching brief	Monitor sales of adaptation goods and services within the UK, and by UK companies.
<p>Source: CCRA2 Evidence Report, Chapter 6.</p> <p>Notes: Urgency scores have been determined by the ASC on the basis of the evidence presented in the chapter. See Chapter 2 of the Evidence Report for a description of the urgency scoring methodology.</p>		

Source: Synthesis Report, UKCCRA2 [73]

Appendix 5 – Post-UKCCRA1 reports available to UKCCRA2

Comment [JB1]: No source

Source (title, author, date)	Risks assessed (direct or indirect impact)	Opportunities assessed (direct or indirect impact)	Quan.?	Qual.?	Sector and company?	UK only or UK plus international?
Baglee, A., A. Haworth and S. Anastasi. 2012. "Climate Change Risk Assessment for Business, Industry and Services Sector". DEFRA.	Key Risks (Tier 2 analysis) BU1 to BU10 from UKCCRA1	-An expansion of new or existing tourist destinations in the UK (BU8) (indirect)	Y but lacking	Y	Financial services; tourism; food and beverages; primary extractives (oil, gas and mining) and chemical manufacturing Size: SMEs to large multi nationals	UK but consideration of international perspective (e.g. Global supply chains). UK only CCRA is not representative of the global market in which the UK operates.
Ballard, D., C. Bond, N. Pyatt, K. Lonsdale, G.P. Whitman, S. Dessai, M. Evans, and J.H. Tweed. 2013. "PREPARE - Barriers and enablers to organisational and sectoral adaptive capacity - qualitative study", Part of the PREPARE Programme of research on preparedness, adaptation and risk, Final Report for project ERG1211 by Ricardo- AEA for Defra. Report reference Ricardo- AEA/R/ED58163/PREPARE	<ul style="list-style-type: none"> - Concern of businesses regarding climate change – one in 6 (17%) of all organisations are concerned about extreme weather but are not to not at all concerned about the impacts of climate change on the UK. - Businesses are 46% fairly concerned about the effects of climate change on the UK (25% not very concerned, 19% very concerned) - In 2012 31% of businesses surveyed were significantly affected by extreme events 		N	Y	All organisations but 1700 businesses were surveyed and business results separate.	UK only

R1a/Issue 1.0						
Hoekstra, A.Y. 2014. "Water scarcity challenges to business". Scientific American.	<ul style="list-style-type: none"> - Operation and supply chain risk from water shortage and pollution and stricter regulation (higher water prices, reduced rations, stricter emissions permits or obligatory water saving technology) - Unsustainable water use may impact reputational risk 	<ul style="list-style-type: none"> - Mitigating strategies for reducing water consumption may give a competitive advantage BUT may need regulation - Disclosure driven by environmental organisations and the investment community - Product transparency through labelling to certification 	Y	N	Businesses	Global
Risky Business Project. 2014. "The Economic Risks of Climate Change in the United States – A Climate Risk Assessment for the United States". Risky Business	Damage to coastal property and infrastructure from rising sea levels and increased storm surge, climate-driven changes in agricultural production and energy demand, and the impact of higher temperatures on labour productivity and public health.		Y	N	Agriculture, energy and coastal infrastructure	USA only
Nicholls, R.J. and A.S. Kebede. 2012. "Indirect impacts of coastal climate change and sea-level rise: the UK example". Climate Policy Vol. 12.	Sea level rise on coastal infrastructure (direct), disruption of supply chains (indirect), security threats from forced migration (indirect) Decline in national prestige (indirect), impacts on finance and insurance industries (indirect)	<p>The potential for export of world-leading coastal hazard and management expertise</p> <p>Benefits to national prestige conferred by a strong response to climate change</p>	Y	Y	Infrastructure in particular energy, transport, water	Global
MCCIP. 2013. "Marine climate change impacts Report Card 2013". MCCIP.	Loss of primary production up to 20% in UK northern regions (Central and northern North Sea)	Rise in primary production in southern UK (Celtic Sea, English Channel)	Y	Y	Fisheries industry	UK
Surminski et al (2013), Response to public	Impacts of flooding on residential and commercial properties (indirect)		Y		Residential and businesses	UK

consultation on 'Securing the future availability and affordability of home insurance in areas of flood risk'						
Surminski, S. and J. Eldridge. 2015. "Flood insurance in England - an assessment of the current and newly proposed insurance scheme in the context of rising flood risk". Journal of Flood Risk Management.	Flooding	To readdress the design and scope of flood insurance- including risk reduction	N	Y	property	UK and wider scope
European Commission. 2013. "Green Paper on the insurance of natural and man-made disasters". EC.	Long term impact of climate change where insurance is not customary may impact affordability and availability	Action at EU level could facilitate improved market for insurance	Y	Y	Insurance industry	EU
Ranger, N. and S. Surminski. 2013. "A preliminary assessment of the impact of climate change on non-life insurance demand in the BRICS economies". International Journal of Disaster Risk Reduction 3.	Emerging markets may be more vulnerable to the impacts of climate change	Insurance industry market growth in emerging economies	Y	Y	Insurance industry	Global – emerging economies
Surminski, S. 2013. "Private-sector adaptation to climate risk". Nature Climate Change 3.	Risks to business operation	Development of climate information service tools and technologies, climate, production and service for climate goods e.g. insurance	N	Y	Multi sector	Global
Arup. 2009. "Climate Change Impacts and Responses for Key Business	Transport infrastructure is vulnerable to weather conditions				Multi sector	UK

Sectors and Public Services in the Northwest of England". Final Report, Arup.						
ASC. 2014. "Managing climate risks to well-being and the economy". ASC.	Current and future risks and opportunities to business and infrastructure providers. Includes disruption to transport, energy, water and ICT networks due to current weather.	Summary of adaptation goods and services opportunities, including patent data and comparative advantage analysis	Y	Y		UK plus international
PwC. 2013. "International Threats and Opportunities of climate change for the UK". PwC.	Current and future risks originating from outside the UK. Focus on trade and food supply chains	Export opportunities	Y	Y		UK plus international
Foresight. 2011. "International Dimensions of Climate Change". Final Project Report, The Government Office for Science, London	Reports on impact of climate change overseas on commodity prices, the financial sector and large multi-national companies in the UK		Y	Y		UK plus international
Frontier Economics. 2012. "Economics of Climate Resilience (ECR) – CA0401".	(i) internal operations: affecting plant, stores or other activities in particular locations and their use of shared assets or infrastructure; (ii) value chain: 'upstream' suppliers, associated inputs and 'downstream' consumer markets; and, (iii) strategy and markets: demand in existing markets and opportunities for new markets	New market opportunities	Y	Y	Multisector	UK and supply chain
IPCC 5 th Assessment Report (2014)	Economic activity in key economic sectors and services on economic welfare, and on economic development - More energy demand for cooling for residential and commercial - Climate change will affect different energy sources and technologies differently, depending on resources (water flow, wind,	-Less energy demand for heating for residential and commercial - Water supply, infrastructure and water demand- positive and negative and varying in scale and intensity	Y	Y	Multisector	Global

	insolation), technological processes (cooling) or locations (coastal regions, floodplains) involved - the integrity and reliability of pipelines and electricity grids - Water supply, infrastructure and water demand - Negative effect on transport infrastructure - Effect on tourism resorts - Effect on insurance systems - Effect on healthcare systems	- Effect on tourism resorts - Well functioning markets may reduce negative impacts and promote positive ones				
Annual Report of the Government Chief Scientific Adviser. 2014. "Innovation: Managing Risk, Not Avoiding It". The Government Office for Science, London 2014.	Innovation and risk- particularly to infrastructure (direct and indirect), with 5 broad categories of innovation: - Benefits of innovation is accepted but disagreement on who pays - Wider benefits accepted but imposition of high costs and impacts - Debate is about values- 'early-stage innovations' - Unanticipated consequences - New challenges - Challenges and benefits of regulating innovation	Innovation – as an opportunity	Y	N	Multisector	local, national, European and global scales
Climate Ready. 2013. "How to prepare a climate change action plan: Food and drink sector guidance". Climate Ready.	Assessment of climate risks to business - direct and indirect	Opportunity to strengthen supplier relationships and increase oversight of supply chain, strengthening supply chains may benefit company	Y	Y	Food and drink	Local but greater outlook to supply chains
Food and Drink Federation. 2013. "2013 Case Studies: Nestle UK".	Business risk	Opportunity to raise awareness, build adaptive capacity	Y	Y	Nestle UK and Ireland including supply	UK and Ireland and supply chains

					chains	
Environment Agency and Cyfoeth Naturiol Cymru. 2013. Current and future water availability	Risks to water resource in particular to electricity sector		Y	Y	Water resource	UK
Bosher, L. 2013. "Flood Risk Management and the Roles of the Private Sector in England". UNISDR.	Disaster and flood risk	Positive and negative role of private sector	N	Y	Insurance	UK
IEMA (Institute of Environmental Management and Assessment). 2013. "CCA Business Case Guidance". Available at: http://www.oldsite.iema.net/readingroom/articles/cca-business-case-guidance	Weather impacts, dependency of company on the state of the environment and the services it provides	Opportunities on the back of other projects and developments, competitive advantage from resilience, 'early mover' opportunities	N	Y	Multisector	UK and wider
Evans, K. (2013), Assessing the vulnerability of UK business to climate change: A literature review	Climate change and extreme weather, direct and indirect consequences to a particular to a business sector <ul style="list-style-type: none"> • Regulatory risk • Physical risk • Reputational and • litigation risks 	New markets for goods and services to emerge	Y	Y	<ul style="list-style-type: none"> • Oil and gas (extractive) • Real estate and property business sector • The chemical industry • Financial • SMEs • Tourism • Food and beverages • Healthcare • Telecom. 	UK and wider – import/export
Climate North-East. 2012. "Business attitudes, perceptions, exposure and	Extreme weather	40% of the businesses surveyed agreed that climate change could	N	Y	Businesses located across North	North East England, UK

vulnerability to climate change – Executive Summary”. Climate North-East.		present opportunities for their business			East England	
Tomorrow’s Company. 2013. “Partnerships between business and local organisations to tackle the impacts of climate change”. A report for Climate Ready Environment Agency.	Extreme weather; flooding, drought, heatwaves	New markets	Y	Y	Multisector	East of England (and wider UK)
Climate UK. 2012. “A Summary of Climate Change Risks for South East England”. Climate UK.	Flooding Overheating Extreme weather impacts	<ul style="list-style-type: none"> - Innovative building services and urban planning in the UK and overseas - increased yields in agriculture and longer growing seasons, enable growth of more “continental” crops such as grape vines and sunflowers - benefits for tourism due to warmer weather - Reduced heating costs 	Y	Y	Multisector	South East England
Department for Business, Innovation and Skills. 2013. “Adaptation and Resilience (Climate Change) (ARCC): Report for 2011/12”.		Attempts to measure size of the adaptation goods and services sector. Similar to LGA report.	Y			UK (with export figures)
UK Trade & Investment. 2011. “Adapting to an Uncertain Climate: A World of Commercial Opportunities”.	Survey of both opportunities and risks with in-depth qualitative review of finance, construction, professional services and agriculture and life sciences sectors		Y			UK and international

UK Trade & Investment.						
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Source: Authors.