1. Introduction

> Insurance is a means of constructing the promise of economic security in a precarious and uncertain world (Knights and Vurdubakis 1993, p.734).

This thesis takes as its starting point an interest in the relationship between anthropogenic climate change (IPCC 2007b) and the insurance system. The insurance system is defined as including all forms of social insurance such as state-provided universal health care and other provisions of welfare states, as well as commercial forms of insurance. The study is a transdisciplinary (Rosenfield 1992; Albrecht *et al.* 1998; Max-Neef 2005; Steiner and Posch 2006) exercise, conducted in the tradition of sustainability science (Rosenfield 1992; Bolin *et al.* 2000; Kates *et al.* 2001; Max-Neef 2005; Komiyama and Takeuchi 2006; Steiner and Posch 2006; Jäger 2009; American Association for the Advancement of Science 2010), and adopts a complex adaptive systems (CASs) approach (Chu *et al.* 2003; Bradbury 2006; Finnigan 2006; Lebel *et al.* 2006; Liu *et al.* 2007; Waltner-Toews *et al.* 2008). CASs are systems comprising many strongly interacting and changeable elements, with the capacity to adapt over time in response to changes in conditions (Waldrop 1994). Social-ecological systems (SESs) are a subset of CASs: those CASs comprising human-social and ecological elements (Berkes and Folke 1998; Levin 1998). Complementing the CASs approach, this thesis makes use of disciplines from across the social-natural sciences divide. These are critical political economy (*e.g.* Paterson 2001; Levy and Newell 2005), sociology of risk (*e.g.* Beck 1992), climate science and Earth systems science (IPCC 2007a; Hansen *et al.* 2008; Solomon *et al.* 2009), as well as an approach to probabilities (*e.g.* Allen *et al.* 2007) originating in epidemiology and applied to the climate system.

The insurance system is a broad and embracing concept in this thesis. Conceptualised as an SES, it includes for-profit and mutual insurers, government providers of insurance, reinsurers, specialised service suppliers such as loss modellers and brokers, regulatory authorities and industry representative bodies. The term also includes the legal and institutional frameworks created and used to facilitate access to insurance. Investors in insurance companies as well as insurers' own substantial investments are included. The insurance system comprises all the elements and relationships within it necessary to perform the important socio-economic functions of transferring and pooling financial risks.

For the purposes of this thesis the insurance system is delineated as a key subsystem of the global, carbon-based economy, acting as a primary financial risk governance tool. A definitive financial value for the insurance system overall is elusive: incomplete data are available for elements of the insurance system. However, including both commercial and publicly-funded social insurance gives rise to an overall insurance system that is a significant component of the global economic system. A conservative estimate values the insurance system at more than US$8 trillion (in 2007 – Chapter Five, paper C). This represents at least 15% of global GDP of US$54 trillion in 2007 (Swiss Re 2008, p.8). Of the estimated ~US$8 trillion value of the system overall, ~US$3 trillion (in annual expenditure) represents social forms of insurance and ~US$5 trillion (in annual revenue) represents commercial forms of insurance.

Since the early 1990s there has been the expectation that commercial insurers – one element of the insurance system – might demonstrate leadership on anthropogenic climate change mitigation (Paterson 2001).

> From about 1993 onwards, insurance companies, worried about increases in pay-outs for large-scale weather-related disasters (mostly hurricanes and floods) and the possible connections between increases in the frequency and intensity of such events and global warming, have become involved in political debates over climate change (Newell and Paterson 1998, p.696).

Yet as discussed in Chapter Four (paper B), the hoped-for leadership on mitigation originating in the insurance system has not eventuated.

Anthropogenic climate change remains unmitigated (Global Carbon Project 2009b). The implications of anthropogenic climate change for the insurance system is the basic research question that drove this PhD research. Thus the research first calls for identification and characterisation of anthropogenic climate change as a threat, an opportunity, or perhaps both, from the perspective of the insurance system. If anthropogenic climate change is a threat to the insurance system, it may be manageable through adaptation. The threat may be serious and strategic, perhaps even a threat to the existence of the insurance system as it is currently structured.

Insurance is an important element of the contemporary global economy, particularly in more economically developed countries and regions (Pfeffer and Klock 1974; Mills 2009). Historically too, insurance has played a significant socio-economic role, associated since ancient times with the expansion of commerce, and with economic growth more generally (Trennery 1926; Supple 1984; Westall 1984). Therefore the nature of the potential threat that anthropogenic climate change implies for the insurance system is an important research aim.

A second related aim of this research follows from the first: if and how the insurance system might reorient towards effective and just mitigation[1]. Just as climate change is anthropogenic, so

[1] 'Ecologically effective' mitigation is defined in Chapter Five (paper C) as mitigation that delivers cuts in anthropogenic emissions sufficiently rapidly and deeply to avoid dangerous climate change. 'Just' mitigation is

too will be its mitigation. Mitigating anthropogenic climate change is a massive challenge, and surely one that requires contributions across human societies, including from the insurance system. Thus the second aim seeks a solution to the problem defined through addressing the first research aim.

A third research aim concerns theoretical insights yielded in the course of addressing the first two research aims above. This exercise in theory development called for reflection on the process and outcome of responding to the initial two research aims. Pursuing the third research aim entailed exploring linkages between complexity theory and political economy theory.

Anthropogenic climate change is a crisis, but it is a protracted crisis: several hundred years in the making. It will not have passed by next week or next year, next decade or even next century (Solomon *et al.* 2009). Anthropogenic climate change is a catastrophe, and one that continues to unfold (Hamilton 2010). Collectively humanity is yet to mitigate anthropogenic climate change effectively and justly. It is against that backdrop that this research project investigates the anthropogenic climate change-insurance system relationship.

1.1 Scope

The breadth of this thesis is limited to the relationships among the Earth system, the global economy, and the insurance system. The thesis' scope encompasses three related parts. Firstly, identification and definition of a problem, *i.e.* the implications of anthropogenic climate change for the insurance system. Secondly, the thesis explores the potential for a solution to the defined problem, *i.e.* a role for the insurance system in mitigating anthropogenic climate change. Lastly, the thesis reflects on the process and outcomes of the problem definition and solution creation exercises in order to generate new insights into potential further development of the theoretical approach applied in the thesis. This third research aim is developed in the context of both (i) limitations of existing theoretical approaches to the anthropogenic climate change-insurance system relationship, and (ii) limitations in theory revealed through the use of existing theory in pursuing this study's research aims. The thesis therefore begins with highly policy-relevant research aims centred on problem identification and potential solutions. From there, the thesis engages in theory review and development.

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discussed in Chapter Seven (paper E) and usage of the term is consistent with the concept of climate justice (e.g. FOE Australia 2006; Gupta 2007).

1.2 Research aims

The three parts comprising the thesis' scope correspond to three overarching research aims which anchor the project. Each of the three research aims is recast in the form of two specific research questions, *i.e.* six in total. The thesis responds to the six specific research questions, and in so doing addresses the three overarching research aims.

Overarching research aims and the specific research questions devolved from them are:

1. What does anthropogenic climate change mean for the insurance system?
    a. If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, *i.e.* is the threat temporary, intermittent, permanent, strategic, or existential?
    b. To what extent might anthropogenic climate change present an opportunity to the insurance system?

These research questions are addressed in Chapters Three (paper A), Four (paper B), Five (paper C) and Six (paper D).

2. How might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?
    a. How has the insurance system approached anthropogenic climate change to date?
    b. If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?

These research questions are addressed in Chapters Four (paper B), Five (paper C) and Six (paper D).

3. How might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?
    a. What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?
    b. If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?

These research questions are addressed in Chapter Seven (paper E).

As articulated, responses to all of the specific research questions are spread across the papers located in the PhD's various chapters. Table 1.1 at the end of this chapter summarises overarching research aims, specific research questions, responses, and their locations in this thesis.

1.3 Thesis structure

This thesis is structured in support of the three overarching research aims, recast as six specific research questions, as outlined above. Chapter One (this chapter) introduces the thesis overall, and the insurance system as conceptualised for this research project. This chapter also formalises the scope of the research, articulates the guiding research aims and provides the specific research questions devolved from the research aims. Chapter Two systematically outlines the research design adopted for this project, addressing the theoretical framework applied for the study, including the methodology and methods adopted. Chapter Two also provides context for the theoretical framework, in the form of discussion of transdisciplinarity, sustainability science and CASs approaches, each as related to this project, and complementarities between each. Research questions are addressed in subsequent chapters of the thesis.

Chapter Three does two things. Firstly, it provides a brief review of the literature on anthropogenic climate change, insurance, and the insurance-anthropogenic climate change relationship. Secondly, the chapter provides a snapshot and a personal view (paper A) of the process and outcomes of the December 2009 Copenhagen climate negotiations. Chapter Four (paper B) provides a novel critique of both insurance system responses to anthropogenic climate change and an attendant political economy perspective on the relationship between insurance and anthropogenic climate change.

Chapter Five (paper C) proposes reflexive mitigation as an ecologically effective insurance system response to dangerous anthropogenic climate change. Effective and just anthropogenic climate change mitigation requires deep and rapid cuts in greenhouse gas emissions and the conservation of carbon sinks. Chapter Six (paper D) provides a proposal for insurance system engagement in strong anthropogenic climate change mitigation through cutting emissions. The proposal is a theoretically viable expression of the reflexive mitigation concept developed in Chapter Five (paper C), informed by the CASs approach to the anthropogenic climate change-insurance system relationship adopted in this thesis.

Chapter Seven (paper E) reflects on the preceding application of theoretical analysis (in pursuit of problem identification and characterisation, and solution creation), and builds theory on that basis. Chapter Seven thus represents a shift from application of theory to reflection on theory as applied in this thesis.

Discussion of the study's findings is provided in Chapter Eight, and includes consideration of the implications of the study's responses to the original research aims. Chapter Eight additionally includes some comments on potential directions for future research indicated by this project.

Chapter Nine concludes the thesis with some closing reflections on the course of the research project and the prospects for successfully mitigating climate change.

Chapters Three, Four, Five, Six and Seven each include a stand-alone paper. Iterations of Table 1.1 are presented in each chapter, immediately preceding each stand-alone paper. Tables are included to show clearly the specific contribution of each paper in the context of the thesis overall. Each new iteration of Table 1.1 also summarises the accumulated contributions of papers to the thesis' responses to research aims and questions, as articulated in Section 1.2.

1.3.1 Research aims, questions, and response locations

Table 1.1 summarises the structure of the thesis with reference to research aims, questions, and locations of responses in this thesis.

Table 1.1: Research aims, questions and response locations

1	**Research aim: what does anthropogenic climate change mean for the insurance system?**
1.a	Research question: If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, *i.e.* is the threat temporary, intermittent, permanent, strategic, or existential?
	Response locations: • *Chapter 3/paper A;* *Chapter 4/paper B; and* *Chapter 5/paper C.*
1.b	Research question: To what extent might anthropogenic climate change present an opportunity to the insurance system?
	Response locations: • *Chapter 4/paper B;* *Chapter 5/paper C; and* *Chapter 6/paper D.*
2	**Research aim: how might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?**
2.a	Research question: How has the insurance system approached anthropogenic climate change to date?
	Response location: • *Chapter 4/paper B.*
2.b	Research question: If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?
	Response locations: • *Chapter 5/paper C; and* *Chapter 6/paper D.*
3	**Research aim: how might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?**
3.a	Research question: What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?
	Response location: • *Chapter 7/paper E.*
3.b	Research question: If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?
	Response location: • *Chapter 7/paper E.*

2. Research design and context

> We have options, but the past is not one of them (Sauchyn and Kulshreshtha 2008, p.295).

This chapter outlines the context, rationale and design for the research process adopted in pursuit of the research aims driving this PhD. As noted in Chapter One, the study applies a transdisciplinary methodology, develops this in the context of the tradition of sustainability science, and adopts complexity as a theoretical perspective. This chapter discusses and demonstrates complementarities between the above elements, considering them all to be mutually reinforcing. The research methodology and methods employed for this study are described here.

This thesis' three overarching research aims broadly correspond to engagement in: (i) problem identification and characterisation; (ii) solution creation, and; (iii) reflection on the use of theory in this research, so as to contribute to ongoing theoretical development of complex adaptive systems (CASs) approaches. As such the emphasis of the research design is on theoretical analysis and conceptual development rather than empirical investigation. For example, the thesis uses available research on anthropogenic climate change and on insurance provision to provide a novel analysis of the insurance system-anthropogenic climate change relationship. The research then addresses the implications of the new insights generated by the analysis. The research refers to both the ongoing provision of insurance in a changed climate, and to continuing theoretical evolution of CASs approaches to social-ecological systems. The primary value of the research therefore is the development of a theoretical approach for application to the anthropogenic climate change-insurance system relationship, and the insights generated through this approach.

2.1 Transdisciplinary insight

The thesis aspires to contribute transdisciplinary (Rosenfield 1992; Albrecht *et al.* 1998; Max-Neef 2005) insight into the anthropogenic climate change-insurance system relationship, *i.e.* an understanding that transcends disciplinary boundaries. Rosenfield (1992) explains that a transdisciplinary approach develops and then uses a 'shared conceptual framework drawing together disciplinary-specific theories, concepts, and approaches to address [a] common problem' (Rosenfield 1992, p.1351).

The thesis makes use of disciplines from across the social-natural sciences divide. The theoretical approach is anchored in complexity theory (Levins 1970; Waldrop 1994; Kay 2008), and also draws on other theoretical bases: primarily, political economy (Paterson 2001; Levy and Newell 2005; Levy and Scully 2007) (Chapters Four and Seven) and to a more limited extent sociology of risk (Giddens 1990; Beck 1992, 1995) (Chapters Three and Five). The thesis relies on climate science and Earth systems science (IPCC 2001a; Schneider 2004; IPCC 2007a; Rahmstorf *et al.* 2007; Global Carbon Project 2008a; Hansen *et al.* 2008; Keller and McInerney 2008; Lenton *et al.* 2008; Allen *et al.* 2009; Global Carbon Project 2009a; Kerr 2009; Solomon *et al.* 2009; Washington *et al.* 2009) throughout for insights into anthropogenic climate change and the Earth system (all chapters), as well as an approach to probabilities (Stott *et al.* 2004; Stone and Allen 2005; Frame *et al.* 2006; Allen *et al.* 2007) originating in epidemiology and applied to the climate system (Chapter Six).

There are multiple and conflicting examples of usage of terms indicating supradisciplinarity (Kötter and Balsiger 1999; Balsiger 2004) in the literature, *i.e.* research designs employing more than one discipline. Examples include cross-disciplinarity, multidisciplinarity, pluridisciplinarity, and interdisciplinarity in many forms including relational, exchange and modification interdisciplinarity (Davies and Devlin 2007). Taxonomies of supradisciplinarities are unfortunately inconsistent. Davies and Devlin (2007) for example accommodate transdisciplinarity as one of several forms of interdisciplinarity. Max-Neef (2005) provides for transdisciplinarity as one of five categories, with interdisciplinarity as another. Rosenfield's (1992) framework provides for three categories of 'cross-disciplinary' research (but does not include (single) disciplinarity in the framework). In the light of these inconsistencies, an explanation of transdisciplinarity as used in this research is warranted.

Albrecht *et al.* (1998, p.59) provide a simple and useful taxonomy on research disciplinarities, used here to provide clarity regarding the manner in which transdisciplinarity is used in this thesis. Albrecht *et al.*'s (1998, p.59) taxonomy comprises: (i) single disciplinarity (where a research problem is what a single discipline thinks it to be); (ii) multidisciplinarity (where the research problem is what several disciplines working independently think it to be); (iii) interdisciplinarity (where the research problem is what several disciplines working together agree it may be); and (iv) transdisciplinarity (where the problem is defined as part of an open, dynamic system operating at multiple levels). Transdisciplinary inquiries are also distinct in that they are frequently and explicitly directed at solving 'real world' or practical problems (Taplin 2003), *i.e.* 'generat[ing] knowledge that not only addresses societal problems, but also contributes to their solution' (Lawrence 2010, p.18).

Transdisciplinarity can be cause for unease and is perhaps the least-well understood and practised element of the taxonomy referred to above. Davies and Devlin (2007) for example, with reference to delivery of higher education (*i.e.* learning and teaching as opposed to research), raise concerns about the potential impact of transdisciplinarity on the integrity of traditional disciplines, asking:

> How, in a practical sense, would disciplines continue work done in dedicated disciplinary areas of concern if boundaries were 'dissolved'? What does this mean exactly? How would disciplinary integrity be maintained? How would traditional academic concerns be maintained in attempts to reorganise the curriculum to meet more pressing global challenges? (Davies and Devlin 2007, pp. 8-9).

However, it is not clear, for example from case studies of transdisciplinary research[2], that transdisciplinarity threatens disciplinary integrity. Whilst transdisciplinarity encourages researchers to 'transcend their separate conceptual, theoretical, and methodological orientations' and 'build on a common conceptual framework' (Rosenfield 1992, p.1351), this requires cooperation amongst disciplines, not their dissolution. Furthermore Balsiger (2004, p.409) argues that choosing one amongst several possible supradisciplinary research designs is not 'a rejection of one of the others', and instead is a choice informed in part by the complexity of the problem being investigated.

Brown (2010) develops more precision still in defining transdisciplinarity, distinguishing between bounded and open forms. Bounded transdisciplinary inquiry 'remains based in the established modes of inquiry of the constituent disciplines, although it may be informed by other ways of knowing' (Brown 2010, p.66). In contrast, open transdisciplinary inquiry is 'unbounded by existing limits' and '[does] not privilege the specialist disciplines to the same extent' (Brown 2010, p.66). Open transdisciplinary inquiry 'goes further… to include all validated constructions of knowledge [*i.e.* 'including Indigenous, local and professional' (Dovers 2010, p.184)] and their worldviews and methods of inquiry' (Brown *et al.* 2010, p.4).

With reference to Brown's (2010) nuanced typology, this thesis is as example of a bounded transdisciplinary inquiry, anchored in a complex adaptive systems approach, while drawing on other disciplines: neo-Gramscian political economy, and to a limited extent sociology of risk. Additionally, the thesis relies on Earth system science for analysis of anthropogenic climate change as a globally coherent phenomenon. The thesis also makes use of an approach to probabilities that originates in epidemiology, and has been applied in climate science. Lastly, from the outset and as indicated in the Preface, this study was inspired in part by earlier awareness of the nexus between insurance, human rights, and environmental and social justice. Thus the thesis

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[2] Albrecht *et al.* (1998) present their own 'ecosystem health' research into coronary heart disease in the Hunter Valley coalfields in Australia as one example. Additionally, they cite Kunitz's (1994) work on disease and destruction of New World indigenous populations since 1492 as an example of a transdisciplinary approach as deployed by a singe researcher. Rosenfield (1992) is cited as an example of a team approach, in this case applied to malaria and tuberculosis in the Amazon.

approaches the anthropogenic climate change-insurance relationship as a research problem requiring transdisciplinary analysis.

Research approaches that transcend existing disciplines are absolutely necessary for generating insights into complex problems, including questions linked to ecological sustainability (Steiner and Posch 2006). As Albrecht *et al.* (2001) argue:

> We can no longer see ourselves as separate from the complex natural systems with which we interact. *Humans are now the major force acting on living and non-living systems on the planet.* We can no longer be content with disciplines and fields of knowledge that only attempt to dissect complex, adaptive systems into discrete and manageable parts. Postmechanistic thinking is creative and process oriented, and searches for new, more integrative ways of knowing the world (Albrecht *et al.* 2001, p.70 [italics in original]).

Transdisciplinary analysis is therefore particularly beneficial where the research focus involves CASs, *i.e.* systems with emergent properties. As outlined in Section 2.3, this study conceptualises the insurance system, the global economy, and the Earth system each as social-ecological systems (SESs) in relationship, *i.e.* co-evolving CASs, all with human-social and ecological elements. This study proceeds with the theoretical perspective that accepting and engaging with complexity is necessary where the research aims include generating useful insights about relationships between these three SESs.

As this study draws on both social and natural sciences, there is particular merit in making explicit the ontological and epistemological underpinnings for the study's theoretical perspective.[3] Ontology is the study of being (Crotty 1998, p.10). The thesis adopts a reasonably uncontroversial realist ontological position, *i.e.* the world is real: it exists beyond the researcher's mind.

Epistemology is the study of knowing, and relevant to the research process in that it provides the theory of knowledge embedded in the theoretical perspective, and therefore in the methodology applied to the study (Crotty 1998, p.3). The thesis adopts a constructionist epistemological position (Crotty 1998, pp.42-65), *i.e.* that whilst the world is real, it comes to be known through various ways of knowing. This differs from positivist approaches (Crotty 1998, pp.18-41) in so far as positivist approaches assert reality can be known objectively. Making this explicit is important given the nature of the inquiry. Whilst global warming is 'unequivocal' (IPCC 2007b,

[3] Crotty's (1998) *The Foundations Of Social Research: Meaning And Perspective In The Research Process*, as the title indicates, is directed at social research. However, his discussion of elements of the research process including ontological and epistemological dimensions of research, theoretical perspective, methodology and methods accommodates a research process such as this, which draws on both the social and natural sciences. Crotty's (1998) explication of the research process is used to structure in part this chapter's discussion of the research process adopted for this thesis.

p.5), awareness and understanding of anthropogenic climate change is mediated by processes generating and sharing scientific knowledge.[4] For example, little if any evidence of anthropogenic climate change as a global-scale phenomenon is available directly to individuals without the benefit of training, specialised instruments and vast computer modelling potential (McGuffie and Henderson-Sellers 2005). Anthropogenic climate change is an evolving Earth system phenomenon. Climate science too is continually evolving, and scientific understanding of anthropogenic climate change is continually being refined (*e.g.* Richardson *et al.* 2009). Successive IPCC analyses provide results with increasingly compelling human attribution of climate change (*e.g.* IPCC 2001a, 2007a). More fundamentally, scientific practices continue to evolve, reflecting changes in understandings of what science can – and should – deliver: the evolution of transdisciplinarity as a choice for research approach is one example. The establishment of sustainability science as a tradition in scientific inquiry, discussed in Section 2.2, is another.

This thesis' theoretical perspective acknowledges that meaning is generated through interaction of subject and object: meaning is always layered onto reality as reality is accessed by observers (Crotty 1998, p.9). In summary, this thesis combines a realist ontological position with a constructionist epistemological position. As Crotty (1998) argues, '[r]ealism in ontology and constructionism in epistemology [are] quite compatible' (Crotty 1998, p.11).

2.2 The tradition of sustainability science

The practical context for this research project is completion of requirements for a doctorate in environmental studies (Taplin 2003). Environmental studies is a supradisciplinary field of inquiry:

> concerned with the historical, theoretical, and policy implications of the human construction and transformation of the environment. There is a focus on contemporary environmental concerns, including how and why these concerns have risen to the forefront of current policy agendas, how social, economic and technological systems mediate our interaction with the environment, how these systems vary across the world and evolve with time and the ways in which environmental decisions are made and controversies resolved (UNSW 2010).

This research project's inquiry has proceeded in the evolving tradition in science termed 'sustainability science' (Kates *et al.* 2001; Lowe 2005; Komiyama and Takeuchi 2006; Lowe 2009; American Association for the Advancement of Science 2010). In the context of growing

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[4] Science is not the only way to generate knowledge about the world, but it is a particularly powerful one. Bradbury (2002, p.58) argues '[t]he body of scientific knowledge is not, and cannot be, "the truth", since it is always subject to revision', but neither is science 'relative… no more [useful or correct] than any other way of knowledge… and anything goes'. In Bradbury's view (p.58) scientific 'knowledge is constructed rather than discovered as a fully human activity, but constructed through the application of the most powerful recipe we know. Part of the power of the recipe resides in the way its constructive, creative part is always offset by its destructive, critical part.'

awareness of the threatened collapse of ecosystem services on which humanity is wholly dependent (Millenium Ecosystem Assessment 2005; Lenton *et al.* 2008), sustainability science 'seeks to understand the fundamental character of interactions between nature and society' (Kates *et al.* 2001, p.641), and 'to shape a better general understanding of the rapidly growing interdependence of the nature-society system' (Bolin *et al.* 2000).

Sustainability science is therefore motivated by fundamental questions about the nature-society relationship as well as the compelling and urgent needs of human societies (Clark and Dickson 2003; Clark 2007; Carpenter *et al.* 2009). By way of example, Kates *et al.* (2001) propose an initial set of broad questions that sustainability science could address, including the following, which resonate particularly strongly with this study's research aims:

- How can the dynamic interactions between nature and society – including lags and inertia – be better incorporated into emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?
- How are long-term trends in environment and development, including consumption and population, reshaping nature-society interactions in ways relevant to sustainability?
- What systems of incentive structures – including markets, rules, norms, and scientific information – can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories?
- Can scientifically meaningful "limits" or "boundaries" be defined that would provide effective warning of conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation? (Kates *et al.* 2001, p.641).

Kates *et al.* (2001, p.641) argue that sustainability science 'differs to a considerable degree in structure, methods, and content from science as we know it'. In addressing the core questions above, sustainability science needs to (i) span spatial scales from global to local, (ii) account for both temporal inertia and urgency in system processes, (iii) deal with complexity, and (iv) recognise diversity in perspectives within science and in society more broadly, about what constitutes useful and usable knowledge. Kates *et al.* (2001) further propose three pathways to progress sustainability science: (a) a focus on nature-society relations, (b) ongoing discussion regarding key research questions and applicable methodologies, and (c) connecting science to the political agenda for sustainable development (Kates *et al.* 2001, p.642).

Sustainability science is 'heterogeneous in scope and practice' (Jäger 2009, p.2). Earth system science (*e.g.* Schellnhuber 1999; Earth System Science Partnership 2010) is consistent with sustainability science. It is grounded in the physical sciences, and has an emphasis on planetary scale phenomena and analysis. A matching approach has emerged in the social sciences: Earth system governance (*e.g.* Biermann 2007; Earth System Governance Project 2010). As noted above, this PhD is transdisciplinary and was designed and conducted to draw from both social and natural sciences. The study recognises linkages across the human-social and ecological elements of the SESs being studied.

Bradbury (2006) presents a perspective consistent with Kates *et al.* (2001) above, and one that emphasises the need for sustainability science to engage with complexity. In Bradbury's view, we are currently at a 'Promethean moment', by which he means that:

> there are two big historical processes intersecting at the moment: the coming into being of a fully connected world, and the coming into being of a new way of doing science. Both only make sense from a complexity point of view… These two processes are going to interact incredibly strongly… and that will take us into radically new territory (2006, p.21).

The following sections explore the complexity and CASs aspects of this study.

2.3 Theoretical perspective: Complexity and complex adaptive systems

'Theoretical perspective' as applied to the research process is 'the philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria' (Crotty 1998, p.3). This thesis adopts a complexity or CASs approach (Waldrop 1994; Albrecht *et al.* 1998; Levin 1998; Albrecht *et al.* 2001; Gunderson and Holling 2002; Scheffer *et al.* 2002; Holling 2004; Lebel *et al.* 2006; Walker *et al.* 2006; Liu *et al.* 2007; Waltner-Toews *et al.* 2008; Norberg and Cumming 2009) to the relationships between the Earth system, the global economy and the insurance system.

Complexity has become a focus found across physical sciences, social sciences, and humanities (Hartvigsen *et al.* 1998; Milne 1998; Thrift 1999; Anderson *et al.* 2005; Urry 2006). Complexity is a motivation for transdisciplinary research approaches (Steiner and Posch 2006), and one of the motivations for the emergence of the sustainability science tradition (Kates *et al.* 2001). Yet 'there is still no generally accepted definition of complexity' (Chu *et al.* 2003, p.19). 'Complexity theory' is used to refer to 'a number of theories concerned with complex systems gather[ed] under the banner of complexity research', as opposed to 'one identifiable complexity theory' (Manson 2001, p.405). Even then, Manson argues, '[t]he exact nature of complexity research is hard to discover due to the large degree to which complexity ideas are traded across disciplinary boundaries' (Manson 2001, p.405).

Complexity's heritage is in systems thinking. Kay (2008) traces the origins of modern systems thinking to von Bertalanffy's work in evolutionary biology beginning in the 1920s and his general systems theory (Bertalanffy 1968), and also notes the spread of systems approaches in fields as diverse as anthropology, physiology, mathematical biology, cybernetics and management sciences. Whilst systems thinking originated in natural systems fields, human and mechanical systems also adopted the approach, which concerns itself with 'connectedness, context, and feedback… interactions, relationships and patterns… [u]nderstanding comes from looking at how… parts operate together rather than from teasing them apart' (Kay 2008, p.7). Kay (2008, p.8) describes complex systems thinking as the 'grandchild of von Bertalanffy's general systems theory', emerging in the wake of new science of the 1970s including chaos theory originating in meteorology (Lorenz 1963; Gleick 1993), nonequilibrium thermodynamics and complexity approaches.

Manson (2001, p.406) argues complexity research offers insights that previous systems work did not, two aspects of which are discussed here. Firstly, complexity research extends beyond systems approaches through its focus on non-linear relationships between constantly changing entities within a system. In contrast, systems theory focuses on static entities linked by linear relationships. Secondly, complexity research acknowledges and seeks to understand emergence, *i.e.* unexpected and different behaviour evolving from relatively simple interactions between elements in a system. Aligned with this is the potential for complex systems themselves to change and evolve over time. In contrast, traditional systems approaches assume systems exist or remain in equilibrium states: as such there is no call to explore changing relationships between changing system elements.

Waldrop (1994, p.13) describes complexity theorists as generating a 'rigorous alternative to the kind of linear, reductionist thinking that has dominated science since the time of Newton – and that has now gone about as far as it can go in addressing the problems of our modern world'. As envisioned in the mid 1980s, 'instead of being a quest for the ultimate particles, it would be about flux, change, and the forming and dissolving of patterns… Instead of being about simplicity, it would be about… complexity' (Waldrop 1994, p.17). Complexity approaches therefore represent a profound shift in mindset in science, with implications for understandings of both how the world is and how science functions.

2.3.1 Complex adaptive systems (CASs)

In Waldrop's (1994) view, CASs are systems with four specific characteristics. Firstly, CASs are complex, meaning they are comprised of independent and changeable elements, interacting with each other in diverse ways (Waldrop 1994, p.11). Secondly, CASs have capacity for emergence (also referred to as spontaneous self-organisation). Elements within CASs co-evolve as they adapt to each other, changes in each other, and other system changes. The co-evolutionary process creates order and novelty (Waldrop 1994, p.11 and p.259). Thirdly, CASs are adaptive: as CASs experience perturbations, whether internal or external, CASs attempt to adapt to (or learn about) changed circumstances (Waldrop 1994, p.11). Lastly, CASs have dynamism, through the capacity to bring order and chaos into balance (Waldrop 1994, p.12).

The complexity approach (Bradbury 2006; Waltner-Toews *et al.* 2008) is still in its 'infancy' according to Finnigan (2006, p.xi), who argues the approach 'tends to employ an eclectic collection of theories and methodologies designed to deepen our limited understanding of the properties of complex adaptive systems' (Finnigan 2006, p.xi). Chu *et al.* (2003) seek to contribute to further development of the theoretical foundation for complexity science by addressing the possibility of formulating a unified theory of complexity. In doing so, Chu *et al.* (2003) point to CASs as a potential unifying notion:

> Among those who have carefully compared different CAS[s], there is little doubt that they form a coherent subject matter. At the right level of abstraction, their mechanisms and processes can be given a unified description. Within this framework we begin to see common causes for common characteristics… The challenge is how to provide a rigorous treatment of these observations (Holland 1994, p.332, in Chu *et al.* 2003, p.20).

Chu *et al.* (2003, p.20) note that in some areas of academic literature, the term CAS is used synonymously with complexity. 'Complex adaptive systems approach' is used to describe this study's theoretical perspective on the insurance system, the global economy, the Earth system, and the relationships among these systems.

Manson (2001, pp.409-411) presents a typology of complexity approaches in an attempt to provide some order to their myriad applications across multiple disciplines. Without making explicit reference to CASs, Manson's 'aggregate complexity' is in effect a discussion of CASs and CASs research. Manson lists six key attributes of aggregate complexity. Manson's listing complements Waldrop's above, and as such is helpful for conceptualising CASs.

The first key attribute of Manson's (2001) typology is relationships, the 'heart' of aggregate complexity, and more important than a system's constituent parts for defining the system. Subsystems and individual components of a system typically have functions or goals but, given the complexity of the relationships within the system, it is not possible to characterise the system overall as having a unified purpose. Secondly, relationships and their dispersion within a system are not uniform: some relationships and sets of relationship are tighter and more strongly interacting. The overall effect is a sense of structure within the system. Thirdly, defining any system (other than the universe) means delineating a boundary within which lies the system, and outside of which lies its environment or context.

Fourthly, a system 'remembers', in the form of persistent internal structures. Manson (2001, p.410) suggests, for example, that ecological system memory manifests as varying configurations and densities of relationships within and between species; economic system memory lies in documents such as business plans and in individuals' experience. Fifthly, emergence: CASs can generate novel qualities and characteristics 'that are not analytically tractable from the attributes of internal components' (Manson 2001, p.410). Lastly, CASs change constantly, for example through changes in their internal structures to better engage with their environments. CASs are also subject to perturbations, both internal and external, which can result in reorganisation and retention of essentially the same system characteristics, or a shift in the system from its current state to an alternative state.

CASs can be conceptualised at multiple scales, and in multiple contexts. Meek *et al.* (2007) note that the term CAS tends to be applied particularly to systems in which humans are elements, such as geographical regions or human social institutions such as firms and other organisations. The next section explores CASs with human-social and ecological elements.

2.3.2 Social-ecological systems (SESs)

Social-ecological systems (SESs) are a subset of CASs. SESs are CASs comprising co-evolving human-social and ecological elements, and which interact with other SESs (Berkes and Folke 1998). Gunderson and Holling (2002) developed the concept of 'panarchy' to refer to the manner in which smaller systems can be nested within larger systems, and the potential for bidirectional cross-scale impacts between systems in such a panarchy.

As with complexity theory generally, CASs approaches to SESs are still very much in flux, and continue to be advanced (Gallopín 2006; Janssen and Ostrom 2006; Walker *et al.* 2006). The concept of resilience has evolved, together with vulnerability and adaptive capacity, to provide a substantive foundation for what have come to be termed resilience approaches (or 'resilience thinking' (Walker and Salt 2006) to SESs (Adger 2006; Folke 2006; Gallopín 2006; Smit and Wandel 2006). This thesis employs and also critiques resilience approaches to SESs in its attention to the relationships between the insurance system and the larger systems within which it is nested *i.e.* the global economy and the Earth system. The next section introduces insurance conceptualised as an SES in this thesis, *i.e.* as a CAS with human-social and ecological elements, nested within the global economy, in turn nested within the Earth system. The global economy and the Earth system are also introduced as SESs in Sections 2.3.4 and 2.3.5.

2.3.3 The insurance system

The insurance system as conceptualised for this research project comprises all forms of social insurance such as state-provided universal health care as well as commercial forms of insurance. This approach is articulated in detail in Chapter Five (paper C) and is noted here to introduce the

CASs approach adopted in the thesis. The conceptualisation is made broadly and includes for-profit and mutual insurers, government providers of insurance, reinsurers, specialised service suppliers such as loss modellers and brokers, regulatory authorities and industry representative bodies. The term also includes the legal and institutional frameworks created and used to facilitate access to insurance. Investors in insurance companies as well as insurers' own substantial investments are also included. Conceptualised this way, the insurance system is a key subsystem of the global, carbon-based economy, acting as a primary[5] financial risk governance tool in the economy.

This thesis refers to 'insurance system' in the singular. Willard Gibbs, a pioneer of systems thinking, defined a system as:

> any portion of the universe [including ourselves and everything we have created, such as social systems] which we choose to separate in thought from the rest of the universe for the purpose of considering and discussing the various changes which may occur within it under various conditions (in Rukeyser 1964, p.445).[6]

Establishing the financial value for the insurance system overall is very difficult. The data available for elements of the insurance system including both commercial and publicly-funded social insurance are incomplete but do suggest that the insurance system overall is a significant component of the global economic system. As discussed in Chapter Five (paper C), a conservative estimate of the value of the insurance system is in excess of US$8 trillion (in 2007). This represents at least 15% of global GDP of US$54 trillion in 2007 (Swiss Re 2008, p.8). Of the estimated US$8 trillion value of the system overall, more than ~US$3 trillion (annual expenditure) represents social forms of insurance, and at least ~US$5 trillion (annual revenue) are in commercial forms of insurance.

2.3.4 The global economy

The global economy has also been analysed as a CAS (Arthur *et al.* 1997; Beinhocker 2006). Beinhocker (2006) makes a detailed case for the superiority of complexity theory's explanation of economies as disequilibrium systems over orthodox equilibrium accounts. However, whilst

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[5] This thesis describes the insurance system as *a* primary financial risk governance tool. In contrast, Hecht (2008), focussing solely on commercial elements of the insurance system in the US, refers to the insurance industry as *the* primary financial risk governance tool: 'The insurance industry is our society's primary financial risk manager' (Hecht 2008, p.1559). The difference in perspective perhaps stems from variations in breadth of focus. The perspective adopted in this thesis recognises that insurance provision extends beyond commercial elements of the insurance system, *i.e.* to include social forms of insurance. Furthermore, the management of financial and other risks extends beyond the insurance system as a whole. A still broader conceptualisation of risk management acknowledges other, non-formal approaches to coping with risk (*e.g.* Anderson 2005).

[6] See also Rukeyser (1964, p.235).

Beinhocker grounds his economic theory in physical reality, his thesis fails to connect with ecological reality, for example the notion of limits (*e.g.* Meadows and Club of Rome 1972; Meadows *et al.* 2004). In contrast, Daly's (1982) earlier 'steady state economy' approach clearly recognises the social-ecological character of the economy, and in so doing makes the strong argument for a theoretical understanding of economy that recognises Earth system limits.

2.3.5 The Earth system

Both Lovelock's 'Gaia' (Lovelock 1979, 2007) and Crutzen and Stoermer's 'Anthropocene' (Crutzen and Stoermer 2000; Crutzen 2002) convey the sense of a co-evolutionary process engaging ecological and human-social systems at the global scale. Increasing anthropogenic greenhouse gas (*i.e.* carbon dioxide equivalent or CO_2e) emissions causing changes in the Earth's climate, which in turn drive modification of human societies, are emblematic of the linked and co-evolutionary processes of ecological and human-social systems at the global scale. Earth system science and global environmental governance, originating in the natural and social sciences respectively, are research areas grounded in an understanding of the Earth system comprising intertwined ecological and human-social elements (Schellnhuber 1999; Steffen *et al.* 2003; Young *et al.* 2006; Biermann 2007).

This thesis uses CASs approaches to conceptualise each of the Earth system, the global economy and the insurance system, and then to explore relationships among them. Some comments in the following section on the normative dimensions of complexity approaches conclude the introduction of complexity and CASs as adopted in this thesis.

2.3.6 Complexity theory and norms

Ignoring the normative dimensions of theory, whether by accident or design, creates potential pathways to end points which may or may not be desirable. Nevertheless examples in the literature of complexity approaches to environmental governance that acknowledge the importance of norms and power in human-social elements of social-ecological systems (*e.g.* Lebel *et al.* 2006) are few. The norms and power ramifications of theoretical analyses merit introduction.

Waldrop (1994) argues forcefully that complexity undermines the currently dominant argument that maximising individual freedom, *i.e.* an individualised social choice mechanism such as the market favoured by neoliberalism (Brodie 2007), is the best way to achieve an ideal general outcome for human societies.

Firstly, given complexity, there is no ideal equilibrium state for a complex adaptive system such as a socio-economic system, *i.e.* no 'ideal state'. Instead, there are multiple potential states of relative merit, each of which is historically dependent, *i.e.* dependent on conscious decisions, unexpected outcomes and accidents of history.

Secondly, dispersed control and decision-making through a complex adaptive system does not guarantee a 'best' (or realistically, a 'better') outcome. Waldrop (1994, pp.39-48) cites examples of technological change where an inferior technology has attained dominance, *i.e.* 'lock-in', even though the socio-economic system in which it was developed and diffused was characterised by dispersed control and decision-making.

Elsewhere, Waldrop (1994, pp.126 and 330-331) argues in favour of intervening thoughtfully in complex adaptive systems. This approach is consistent with researchers in the global environmental governance area who ground their calls for thoughtful engagement in social-ecological systems in support of resilience and sustainability. Adaptive management and governance (*e.g.* Norberg and Cumming 2009) and social learning (*e.g.* Keen *et al.* 2005) are examples of such approaches. With particular relevance to anthropogenic climate change in the Anthropocene (though without specific reference), Waldrop (p.320) calls for global-scale agreements and treaties to help steer humanity through 'evolution'.

This contrasts with the perspective of neoliberal political theorists who cite complexity in support of arguments favouring minimalist roles for states in markets and societies. Conservative theorists (*e.g.* Beinhocker 2006; Haar 2009), draw on von Hayek (1944; 1960) to argue aspects of a complex physical world, and in particular the inability to make predictions about complex adaptive systems (such as the economy), support a 'natural' superiority of free market non-interventionist socio-economic philosophies, for example neo-liberal non-interventionism. Their naturalistic argument is that if the world is complex and unpredictable, and with potential for emergence, then interventions in support of specific intentions (*e.g.* particular policy outcomes, such as government financing research, development and marketisation of renewable energy innovations consistent with decarbonising the economy) are inefficient and unlikely to succeed. Instead, they argue that dispersed and individualised decision-making, such as (uncritically) attributed to the market, is preferable. Neoliberalism is one such approach, being a recent philosophy (Harvey 2005), as opposed to a 'natural' state of human societies.

There are at least three problems with these arguments of conservative theorists. Firstly, and most fundamentally, 'non-intervention' in a complex adaptive system of which humans and our institutions are important elements is illogical. Humans and our institutions are part of the complexity of the Earth system and the global economy within that, and therefore not external to either. Paradoxically, so-called 'non-intervention' is therefore as much an intervention as any other course of action.

Secondly, whilst the naturalistic interpretation of insights from CASs favoured by conservative political theorists may have some superficial appeal, the argument remains without substance. Irrespective of the state of the Earth system, or the economy, or any other complex adaptive system, the ethics and politics of human responses to changes in them remain choices. Such choices may be judged to be more or less ecologically effective and appropriate (Dryzek 1987). Anthropogenic climate change provides a case in point: both the necessity and the desirability of a collective rather than individualised mitigation response is already established and agreed, through the UNFCCC (United Nations 1992).[7]

Thirdly, the argument is based on a misreading of the prospects for prediction in complex adaptive systems. Ultimately, the Earth system is intrinsically unpredictable. Yet clearly this does not mean prediction is wholly impossible. Etkin (2010, p.20) provides a useful figure representing the familiar path of the state of the Earth system through a well-defined domain over the past 420,000 years, and suggests the pattern may extend back as far as one million years, *i.e.* through ten ice-age cycles. There is (to now) a familiar stability to the Earth system.

Adopting a perspective that is better grounded in human experience, weather prediction for example has been manageable historically because of system stability: past experience has provided a reasonable guide for future experience. In practice CASs such as the Earth system may be more predictable or less predictable, rather than wholly and absolutely predictable or unpredicatble.

A changing climate is a challenge to human societies in part because it renders the Earth system unstable and characterised by unpredictable change (Roe and Baker 2007). Albrecht and Rapport (2002), considering sustainability overall, argue that:

> the world of relative predictability, with respect to reliability of ecosystem functions, has by degrees been transposed to a world of relative chaos in which surprise dominates, often with severe human consequences (Albrecht and Rapport 2002, p.14).

Etkin's (2010, p.20) analysis, referred to above, represents clearly the (geologically) recent and marked shift in the state of the Earth system away from the well-defined domain it has previously occupied.

Attempts to commandeer CASs approaches in support of individualist, voluntarist, and other ineffective responses to anthropogenic climate change are helpful to the extent that their

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[7] Neoliberal anthropogenic climate change denialism is so vitriolic in part because the demands of effective anthropogenic climate change mitigation expose the limited ecological appropriateness of responses consistent with neoliberalism, *i.e.* market responses. In effect the reality of anthropogenic climate change undermines the theoretical foundations of neoliberalism (Aly 2010, pp.84-93).

existence underscores the importance of engaging with norms explicitly when theorising about social-ecological systems, for example resilience approaches. Ideals such as justice, widely accepted as important in human societies, tend not be addressed explicitly in resilience approaches to broader social-ecological systems (Leach 2008). Doing so may usefully contribute to the continued evolution of resilience thinking.

2.4 Methodology and methods

Research methodology is 'the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes' (Crotty 1998, p.3). The research methodology applied in this PhD study was problem driven, consistent with the mutually reinforcing sustainability science tradition, engagement with the complexity of the anthropogenic climate change-insurance system relationship, and an aspiration to generate transdisciplinary insights. The methodology used involved problem identification and characterisation, proposal of solutions, and thoughtful reflection on application of theory. Throughout, the research emphasises theoretical analysis and conceptual development strongly linked to practical application for social transition to global sustainability.

Research methods are 'the techniques or procedures used to gather and analyse data related to some research question or hypothesis' (Crotty 1998, p.3). The research tools for this study were chosen purposively (Burnham *et al.* 2008), *i.e.* as appropriate to the study's overarching research aims. Two methods were required. Firstly, document analysis, applied to sources of climate and insurance data. Secondly, theory building, through engagement with existing theoretical analyses of the anthropogenic climate change-insurance system relationship, and in the creation and application of a novel theoretical approach. The data collection and analysis and theory building aspects of the research are described in the following sections.

2.4.1 Data collection and analysis

Answering this study's research questions (Section 1.2) required access to data and analysis of anthropogenic climate change and the insurance system. Document analysis was deployed as a research method to engage with climate and insurance data and analysis. The thesis relies on publicly available data and analysis generated in the climate science and Earth system science areas to describe anthropogenic climate change as a globally coherent phenomenon within the Earth system. For the first two research aims (Section 1.2) which explore the anthropogenic climate change-insurance system relationship, the Intergovernmental Panel on Climate Change's *Third* and *Fourth Assessment Reports* (IPCC 2001b, 2007c) provided an authoritative source of data and analysis, and this is augmented by reference to more recent studies as published in peer reviewed journals, or available through reliable online data clearing houses such as the Global Carbon Project (Canadell *et al.* 2007; Rahmstorf *et al.* 2007; Global Carbon Project 2008a; Hansen *et al.* 2008; Keller and McInerney 2008; Lenton *et al.* 2008; Allen *et al.* 2009; Rockström *et al.* 2009; Solomon *et al.* 2009; Washington *et al.* 2009; Etkin 2010).

Insurance system data were derived from peer reviewed journals and intergovernmental statistical sources such as the Organisation for Economic Development and Cooperation (OECD 2007) and the World Health Organisation (WHO 2009). Insurance system data were also sourced from grey literature including insurance system actors, such as major reinsurance houses (*e.g.* Munich Re 1973, 2001; Swiss Re 2006) and industry media (*e.g.* Risk Management Magazine 2005; Standard & Poor's 2007, 2008). Policy statements and other publicly available documents produced by insurance system actors such as reinsurers, industry associations and loss modellers are also used (*e.g.* Association of British Insurers 2005; Dlugolecki 2007; RMS 2007; International Chamber of Commerce 2008; Munich Re 2008; Lloyd's 2010).

2.4.2 Theory building

This thesis' trajectory from problem identification and characterisation, through solution creation, to reflection of use of theory in this instance, entailed a substantial component of theoretical analysis, and theory building. The first two aims of the PhD are primarily exercises in developing and applying a novel theoretical approach to the anthropogenic climate change-insurance system relationship with a view to creating new insights. Whilst both demanded some data collection and analysis, both are predominantly exercises in applying and building theory.

The third research aim called for a shift of focus away from the anthropogenic climate change-insurance system relationship itself to reflection on theory as applied to the relationship. This research question explicitly calls for theory building. The third research aim was purposely left somewhat open in the early stages of the research process. The eventual form of the study's response to this aim was partially contingent on the evolution of the research in response to the first two aims (Section 1.2).

Pursuit of the third research aim required little further data collection and analysis. Instead, responding to this aim required reflective engagement with theory, particularly the primary and secondary theoretical approaches used: CASs approaches and neo-Gramscian political economy. The purpose was to explore the potential for linking the two, with the goal of generating a new theoretical approach to better account for the role of politics in SESs in crisis.

This thesis has purposely sought to generate a novel theoretical analysis of the anthropogenic climate change-insurance system relationship. Theory building was anticipated as the major research activity, and eventuated as the main outcome across each of the problem, solution and reflection aspects of the research described in this PhD.

2.5 Conclusion

This chapter has laid out the approach to research employed for this PhD. Transdisciplinarity, sustainability science, and a complex adaptive systems approach are utilised, as three, mutually reinforcing reference points informing the research. Chapter Three reviews the literature context in which the study was conducted.

3. Anthropogenic climate change, the insurance system, and the relationship between the two: The literature context for this research

> Can insurers extend their self-chosen historical role in addressing root causes (as founders of the first fire departments, building codes, and auto safety testing protocols) to one of preventing losses at a much larger scale, namely, the global climate? (Mills 2005, p.1043).

3.1 Introduction

Chapter Three situates this PhD in the areas of academic literature relevant to this research: (i) on anthropogenic climate change; (ii) the insurance system; and (iii) the anthropogenic climate change-insurance system relationship. The first two areas of literature, on anthropogenic climate change and insurance, are massive and multi-faceted. As this literature review is to inform and underpin responses to this study's specific research questions, it is constrained accordingly. The third area of literature, on the anthropogenic climate change-insurance system relationship, has coalesced into two segments. Both are introduced in this chapter.

Much of the literature review for this PhD is provided in the context of papers included in this research, *i.e.* in other chapters. This material is not repeated here, and instead, where relevant, this chapter notes where sections of literature review are provided in papers included elsewhere in this PhD. This chapter also identifies and addresses remaining gaps. Lastly, this chapter concludes with the first stand-alone paper (paper A) included as part of the PhD: the paper provides a brief, personal and comparatively immediate description and analysis of the proceedings of the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 15), held in Copenhagen in December 2009. The account and analysis of COP 15 in Paper A highlights the continuing apparent intractability of anthropogenic climate change mitigation.

3.2 Insurance as a system

Detailed definition and discussion of the contemporary insurance system (introduced in Chapter Two) as conceptualised for this research is provided in Chapter Five (paper C). The present section includes a brief review of the modern insurance system's historical origins and evolution, which supports the conceptualisation of insurance as a system adopted for this research. The brief historical review of the socio-economic role of insurance since antiquity underscores both the continuing centrality of insurance to commerce and economic growth, and the ambivalence of the insurance system with regard to anthropogenic climate change, addressed in Section 3.4.

The conceptualisation of the insurance system for this research is novel in the level of abstraction at which it is applied, allowing a perspective unencumbered by traditional demarcation between key elements of the insurance system, which have previously served as foci for study. For example, commercial insurance in the form of the global insurance industry or sub-elements within it (*e.g.* Leggett 1993; Crichton and Salt 2001; Mills *et al.* 2001; Paterson 2001; Dlugolecki 2008; Hecht 2008; Standard & Poor's 2008; Dlugolecki 2009; Mills 2009), or social insurance in the form of the modern welfare state, in whole or in part (*e.g.* Vettenranta 1986; Pierson 1996; Taylor-Gooby 2002; Niggle 2003; Blomqvist 2004; Clifton *et al.* 2006; Cook 2006). This section gives some attention to both, and is included to provide a sense of the 'shape' and 'character' of the insurance system as conceptualised in this PhD.

Whilst conceptualising insurance as a single system is novel, a broad understanding of insurance and its societal function has been applied earlier. Pfeffer and Klock's (1974) *Perspectives On Insurance* is accurately self-described in the preface as:

> a multidisciplinary approach to the subject of risk and insurance. The insurance business is treated as a major social institution, with private and governmental sectors, that employs a set of techniques for risk management and makes important contributions to personal and business relationships by reducing uncertainty and anxiety (Pfeffer and Klock 1974, p.5).

3.2.1 Brief history

The insurance system has a long history. Trennery (1926) provides an early and thorough investigation of the existence and development of marine (*i.e.* related to shipping and commerce) insurance in the ancient world. According to Pfeffer and Klock (1974, p.272), '[s]hips do not sail and capital is not deployed abroad without adequate insurance protection'. Pfeffer and Klock (1974, p.27) trace the beginnings of insurance as far back as *circa* 2250 BC, to Babylon and insurance provisions in the *Code of Hammurabi*, 'engraved in a block of black diorite about 2.25 meters height… in fragments that were rejoined', after being discovered at the site of the ancient city of Persepolis in 1901.

The literature on historical aspects of insurance focuses on several key themes. Pfeffer and Klock's (1974) analysis identifies the transfer of risk from one party to another as the central idea of insurance and this is common to many studies and definitions of insurance (*e.g.* Melone 1964; Clark 1999). Other historical accounts and analyses point to pooling of risk (*e.g.* Kulp and Hall 1968, p.10). Defining insurance as a system for this PhD includes both risk transfer and risk sharing perspectives.

Other research focuses on the increasing sophistication and expanded use of insurance since its origin, for example through formalisation and standardisation of insurance contracts in the

Middle Ages, and particularly the 13th and 14th centuries (Edler de Roover 1945, p.173). Intellectual developments that connect with the increasing sophistication of insurance are subjects of study, for example the beginnings and development of actuarial science (*e.g.* Haberman 1996).

Histories of long-established individual insurance firms are common.[8] The establishment and rise of insurance firms underscores the social significance of insurance. The fact that histories of insurance have been researched and documented in substantial detail is also indicative of the influential role of insurance houses. Individual studies chart the beginnings of differing lines of insurance, for example life insurance, through key periods of their development and expansion (*e.g.* Clark 1999). This perspective provides a sense of the manner in which the insurance system has expanded beyond limited coverage, against a limited number of risks, in limited geographic areas. Supple (1984) focuses on the place of insurance in British history, and argues that insurance, understood as an economic and financial mechanism, is 'directly associated with… modernisation of economic and social arrangements, and, therefore, with the growth of the British economy from the late eighteenth century' (Supple 1984, p.3).

3.2.2 The contemporary socio-economic role of insurance

As explored in Chapter Five (paper C), the insurance system is now a significant subsystem of the global economy with much broader application, playing a crucial socio-economic role. Chapter Five (paper C) details financial values for social and commercial elements of the global insurance system. This section highlights societal recognition of the socio-economic importance of insurance, and some of the state-industry interaction structures, such as legislative provisions and regulatory frameworks, designed to ensure continuing insurance sector viability.

Governments use insurance to achieve particular policy outcomes. The creation of welfare states (Harvey 2005) is the most comprehensive example of public policy reliance on insurance (Lengwiler 2003). Typical forms of social insurance include publicly funded unemployment benefits, age pensions and universal health care. In modern welfare states, various forms of insurance are both legislated for, and publicly funded. Contemporary western society is deeply dependent on insurance. Lengwiler (2003) goes as far as to describe it as the 'insurance society'.

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[8] Lloyd's for example has many (*e.g.* Brown 1973; Flower and Wynn Jones 1974). Histories of individual firms often also aspire to tell some of the more general history of insurance as an important element of human societies, even though their attention is centred on particular businesses. For example, Dickson's (1960) *The Sun Insurance Office, 1710-1960: The History Of Two And A Half Centuries Of British Insurance* and Supple's (1970) *The Royal Exchange Assurance: A History Of British Insurance 1720-1970*, as the titles indicate, have this ambition.

Insurance has remained important in industrialised welfare states since the 1970s, the period in which many governments have divested themselves of insurance provision to a greater or lesser extent as part of a broader privatisation trend. In the State of New South Wales, Australia, for example, the government insurance office was privatised during the 1990s, as were other publicly-owned financial sector institutions (Walker and Walker 2000, p.84). This shift was in parallel to European trends where, by the end of the 1990s, 'public enterprises in the financial sector [had] declined dramatically and appear[ed] to be on the verge of extinction' (Clifton *et al.* 2003, p.116).

The trend extends beyond the privatisation of whole entities such as government insurance offices, to the privatisation of aspects of what are the key insurance-dependent elements of the welfare state, such as health (Cook 2006). However, neither the retreat from public provision of insurance nor the broader winding back of the welfare state have been complete.

The 2008 global financial crisis resulted in some reversal to privatisation policies, with governments nationalising finance sector businesses in part or in whole (James 2008). The International Monetary Fund, a long-standing champion of neoliberal policies of privatisation, deregulation and marketisation (Harvey 2005) is currently advocating that governments 'provide public support to viable institutions by injecting capital' (International Monetary Fund 2009). Thus the continued need for welfare states including state provision of insurance – and their resilience – remains evident.[9]

States fill gaps in insurance markets by providing access to insurance when a public policy goal or socio-economic benefit is identified, but where risk levels are higher than the insurance market is willing to bear. A further example of government-backed insurance, reprising the purpose of the earliest insurances, is insurance to facilitate export trade. Most industrialised states, and many low income countries too, maintain export credit and investment insurance agencies: public agencies which provide government-backed loans and insurance to firms in order to facilitate high risk exports and overseas investments deemed to be in the national interest (Wright *et al.* 1999; Norlen and Phelan 2002; Phelan *et al.* 2004).

Direct provision of insurance is not the only way that states use insurance in pursuit of public policy objectives. Governments also legislate to require citizens and organisations to buy insurance, but leave provision of the insurance to highly regulated markets. An example of market-based and state-legislated insurance is workers' compensation insurance, such as in New

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[9] As the US Federal government struggled to respond to the global financial crisis, *Newsweek*'s cover carried the headline 'We are all socialists now' (Meacham 2009).

South Wales, Australia, and many other jurisdictions (also noted in the literature - see for example Kulp and Hall 1968). Access to insurance is a public policy goal in its own right, enacted in legislation. Governments regulate their jurisdictions' insurance sectors heavily towards ensuring both continued access to insurance and continued viability of individual firms and insurance sectors overall (Denenberg 1964).

Pfeffer and Klock's (1974) description of regulation of the sector in the US in the early 1970s is instructive. While the details of regulatory arrangements vary from jurisdiction to jurisdiction and over time, the state's regulatory role in the insurance system is clear, and recognisable:

> It has even been suggested that the insurance industry is a public utility, in that the chartering provisions of companies are restrictive, rates are subject to regulation, licensing of agents is designed for the protection of the public, triennial audits are intended to secure performance of obligations, freedom of selection of insureds is somewhat limited, the right to cancel policies is restricted, and a public body has been appointed with the powers of a public utility commission to license corporations seeking to engage in the business and to regulate their practices in specific ways to protect the public. If the full public utility designation has not been yet earned, it is a pronounced trend (Pfeffer and Klock 1974, p.186).

Substantial state oversight of commercial elements of the insurance system reflects political and social recognition of the critical role the insurance system plays in contemporary societies and economies. Threatened and actual collapses of insurance firms are profound events that reverberate throughout financial and public administration systems, and societies more broadly. The decision of the US Federal Board (with the full support of the Treasury) to rescue American International Group – the world's largest insurer – in the midst of the 2008 financial crisis (Federal Reserve Bank of New York 2008) is a case in point. The collapse of HIH Insurance in Australia in 2001 (McIlveen 2001; Commonwealth of Australia [HIH Royal Commission] and Owen 2003) is another.

A functioning insurance system is a critical component of the contemporary global economy. The next section introduces anthropogenic climate change as a phenomenon of the Earth system, with attendant risks, and one with possible implications for the ongoing viability of the global insurance system.

3.3 Anthropogenic climate change

This PhD includes review of the anthropogenic climate change literature to inform the study's responses to the research aims (Section 1.2). The review is presented primarily in Chapter Four (paper B) and Chapter Five (paper C). This section provides some context for this PhD's engagement with anthropogenic climate change, and describes anthropogenic climate change as co-evolving with increasing anthropogenic greenhouse gas emissions since the Industrial

Revolution (*i.e.* eighteenth and nineteenth centuries). This section also introduces the sociological notion of *reflexive risk* to understand anthropogenic climate change as a phenomenon of the Earth system, and one originating in the global economy.

The early days of this research project (*i.e.* early 2007) coincided with a massive broadening and deepening in societal concern globally about anthropogenic climate change, its mitigation and adaptation. Al Gore's film *An Inconvenient Truth* (Guggenheim 2006) had been highly successful in popularising the urgent need to address anthropogenic climate change. During 2007 the Intergovernmental Panel on Climate Change's *Fourth Assessment Report* (IPCC 2007a) was released. In October 2007 the Nobel Peace Prize was awarded to the IPCC and Al Gore jointly, in part motivated by a desire 'to contribute to a sharper focus on the processes and decisions that appear to be necessary to protect the world's future climate, and thereby to reduce the threat to the security of mankind [sic]' (The Norwegian Nobel Committee 2007). The *Garnaut Climate Change Review* (Garnaut 2008) of the economics of anthropogenic climate change mitigation for Australia was commissioned in 2007. In the preceding year the *Stern Review On The Economics Of Climate Change* (Stern 2006) had outlined an economic case at the global scale for mitigating anthropogenic climate change.

The later stages of this research coincide with an altogether changed political atmosphere. The 'Bali Roadmap' (UNFCCC Secretariat 2007), also a product of 2007 (agreed at COP 13 in December that year), was intended to chart a course to binding agreement amongst states at Copenhagen in December 2009 for rapid and deep cuts in greenhouse gas emissions. Despite the two years allocated to preparation culminating in an intense two weeks of negotiations, Copenhagen produced no such result.

This thesis' engagement with anthropogenic climate change emphasises anthropogenic climate change as a phenomenon of the Earth system, a social-ecological system, and with specific attention to its potential impact on the familiar (to humans and our societies) stability of the Earth system (Etkin 2010).[10] Specifying this thesis' particular perspective is important given that anthropogenic climate change invites an extraordinary breadth of inquiry, across interests, disciplines and scales.[11]

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[10] Etkin (2010, p.404) provides an excellent figure which represents clearly anthropogenic atmospheric CO_2 concentrations as driving a radical shift outside of the 'well-defined domain' the Earth's state has occupied for the past 420,000 years. Etkin (2010, p.404, footnote 2) notes that '[o]ther data suggests this pattern has existed for a million years, through ten ice-age cycles'.

[11] Research into anthropogenic climate change originates in the natural sciences (*e.g.* Hansen *et al.* 2008), the social sciences (*e.g.* Paterson 1999), and the humanities (*e.g.* Rosen 2007). Anthropogenic climate change invites inquiry at scales from global (*e.g.* Rockström *et al.* 2009) to local (Bulkeley 2010). The academy is not alone in research climate change; civil society (*e.g.* FOE Australia 2006), governments (*e.g.* Steffen *et al.* 2006), intergovernmental agencies (*e.g.*

In the nineteenth century, climate change began to attract interest as a theoretical subject. In 1827, Joseph Fourier (1827) discovered that the atmosphere overall traps heat; in 1861, John Tyndall (1861) had identified the specific gases that trap heat in the Earth's atmosphere; and in 1896 Svante Arrhenius (1896) provided a calculation for the rise in temperature that would be attributable to a doubling of atmospheric concentrations of greenhouse gases.

In the late twentieth century, climate change transformed from a theoretical possibility pondered by a few to a lived reality for many (IPCC 2001a; Pettit 2004; FOE Australia 2006; Hayward 2006; IPCC 2007a; Weart 2008). Anthropogenic climate change has inspired extraordinary natural science efforts aimed at understanding the phenomenon and its implications, most visibly the review and synthesising work of the Intergovernmental Panel on Climate Change (IPCC), presented in the *First* (and *Supplementary*) (1990 and 1992), *Second* (1995), *Third* (2001) and *Fourth* (2007) *Assessment Reports* (IPCC 1992, 1995, 2001b, 2007c). As alarming as the IPCC's projections have been, '[r]ecent observations show that greenhouse gas emissions and many aspects of the climate are changing at the upper boundary of the IPCC range of projections' (Richardson *et al.* 2009, p.9).

Anthropogenic climate change is not simply a scientific puzzle, but a comprehensive challenge for human societies globally and collectively, by virtue of its unprecedented complexity, scale and magnitude. Emissions – and rates of emissions – continue to rise (Allison *et al.* 2009). Whilst fossil fuel emissions have grown exponentially 'at about 2% per year since 1800', fossil fuel emissions rates since 2000 'have accelerated… to grow at about 3.4% per year, an observed growth rate that is at the upper edge of the range of growth rates in IPCC scenarios' (Raupach *et al.* 2009, p.11). Despite decades of policy discussion, design and implementation, global carbon dioxide (CO_2) emissions rates and atmospheric concentrations continue to rise well beyond (rather than reduce to within) biogeophysical limits: '… the acceleration of both CO_2 emissions and atmospheric accumulation [in the period 2000-2007] are unprecedented and most astonishing during a decade of intense international developments to address climate change' (Global Carbon Project 2008b).

3.3.1 Co-evolution of anthropogenic climate change and industrialisation

Anthropogenic climate change is a direct consequence of the development and growth of industrialising human societies and economies since the Industrial Revolution (Hamilton 2010).

Agrawala and Fankhauser 2008), and business (*e.g.* Association of British Insurers 2005) all take interests in mitigation and adaptation research and policy.

Fossil fuel-based industrialisation is reliant on burning fossil fuels, through which carbon dioxide, the main greenhouse gas, is released into the atmosphere.[12]

Preindustrial atmospheric carbon dioxide (CO_2) concentrations were about 280ppm (Global Carbon Project 2009b). The Global Carbon Project reports that in 2008 atmospheric CO_2 concentrations were 385ppm, 38% higher than since the beginning of industrialisation (*i.e. circa* 1750), and the highest atmospheric concentration of CO_2 in the Earth system in the past two million years at least. As CO_2 emissions continue to accumulate, atmospheric concentrations continue to increase: the average annual increase for the period 2000 to 2008 was 1.9ppm (Global Carbon Project 2009b), to an all time high of 1.3 tonnes per capita (Global Carbon Project and CSIRO 2009). In 2010 atmospheric concentrations are higher still at ~389ppm (Tans 2010).

Crutzen and Stoermer's (Crutzen and Stoermer 2000; Crutzen 2002) 'Anthropocene' concept highlights the significance of climate change and other global-scale anthropogenic perturbations (*e.g.* land clearing) in the Earth system. Humanity is now the primary driver of state change in the Earth system.

3.3.2 New climate risks

Beck's (1992) 'risk society' thesis on late modernity provides a useful theoretical framework for conceptualising anthropogenic climate risk. He argues that the dominant risks in late modern human societies distinguish contemporary societies from preceding forms of modernity. Risk society is characterised by risks which are reflexive and massive: self-generated through human activities, and manifest at unprecedented scales. His key examples are nuclear power, toxic chemicals and genetically modified organisms.[13] Giddens (1990, p.125) similarly addresses new and 'truly formidable' risks. Anthropogenic climate change is a pertinent example with ramifications for future life on Earth. Human intervention is changing global climatic systems, previously understood to be natural phenomena and beyond human influence, into something significantly altered by human activity.

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[12] 'Carbon dioxide (CO_2) is the most important anthropogenic GHG [greenhouse gas]' (IPCC 2007a, p.36). Other greenhouse gases [emissions of which are covered by the UNFCCC] include methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphurhexafluoride (IPCC 2007a, p.36).

[13] Beck (1992, p.88) uses the example of a nuclear power plant to illustrate his thesis: the impacts of a major accident at a nuclear power station can be anticipated to spread well beyond the plant's fence line, and beyond the plant's operational life. The victims will not even all be born at the time of a catastrophe's occurrence. As a result of their high levels of risk and near limitless financial liability, individual nuclear power plants are 'beyond the insurance limit': insurers will not provide liability cover (Beck 1995). Thus the insurance industry makes its own determination about risks, even as scientific and public policy debates about the risks associated with nuclear power wax and wane. Nuclear states have instead created international agreements, for example the 1960 Paris Convention on Third Party Liability in the field of Nuclear Energy, to regulate to some extent liability, losses and compensation (see Hayes and Smith 1993). Such arrangements provide a framework to allow the existence of nuclear power plants, as opposed to a source of sufficient funds to guarantee appropriate financial compensation for possible losses.

Beck's (1992) and Giddens' (1990) theses are not without their critics. Freudenberg (2000, p.111) argues that Beck's and Giddens' focus on risks that 'could involve utter catastrophe' is misplaced, and consequently so is Beck's use of insurability as a 'litmus test' (Beck 1992, p.127) to differentiate between classes of risks. Freudenburg (2000, p.107) offers that the more salient risks for inquiry 'may be more insidious, more invidious and… more corrosive for industrial societies as a whole', and notes specifically the contributory role insurers sometimes play in the effect of such risks. These are risks in which insurers – for better or for worse – have a role, and in some cases 'insurance companies may even have joined in the effort to undermine the legitimacy or 'standing' of victims as part of concerted efforts to reduce the companies' liability after an accident had occurred' (Freudenburg 2000, p.110).

Freudenberg proposes instead that the sociologically significant aspects of risk society stem from massively increased labour specialisation, *i.e.* massively increased societal interdependence leading to reduced capacity for social control of technological advances. The central concern for Freudenberg (2000) is that failures of experts and institutions in an interdependent system, whilst rare, are highly visible and undermine faith in the system itself – beyond the immediate impact of the failure in question.

Arguably Freudenberg (2000) adds a corollary to Beck's (1992) thesis and both perspectives have salience for anthropogenic climate change's socio-economic ramifications. The delineation between insurability and uninsurability does reflect a sense of limits, and therefore provides a useful, if crude, categorisation of risks. However, insurance systems are not simply arbiters of risk. Insurance systems contribute substantially to both the creation of risks and the management of risks in contemporary risk society. For example, insurers continue to provide cover for oil rigs, coal mines, gas pipelines and other greenhouse gas-intensive infrastructure, even as scientific certainty around anthropogenic climate change has been confirmed (IPCC 2007a) – and estimates of current and future economic damages attributable to anthropogenic climate change are very large (Stern 2006; Garnaut 2008). Thus insurance continues to play a crucial facilitative role in the creation of the reflexive risk of anthropogenic climate change.

3.4 The anthropogenic climate change-insurance system relationship

The global insurance system's facilitative socio-economic role impacts in myriad ways, not all of which are positive. Insurance can constitute a perverse financial subsidy, driving increased financial and other losses. For example, Bagstad *et al.* (2007) identify how insurance, together with taxes and other financial incentives, has encouraged building in areas that are prone to adverse weather-related events on the east coast of the US. This is reminiscent of Odum's (1982) research in the same region which drew attention to the way that coastal ecologies can be destroyed by a multitude of small decisions.

In more general terms, the facilitative role insurance has played and continues to play in carbon-based economic activity and growth – and therefore the creation of anthropogenic climate change risks – is clear. Insurance provides a socialised risk management foundation within capitalist economic systems, one which is also necessary for their economic expansion. Insurance does this by providing a degree of socialised limitation to financial risk, and thus a degree of financial certainty. This allows profit-seeking endeavours by individuals and organisations involving levels of financial risk that could or would not otherwise be tolerated.

The literature on the relationship between anthropogenic climate change and insurance is reviewed in detail in Chapter Four (paper B). The existing literature concentrates on commercial elements of the insurance system, *i.e.* commercial insurers, and to a lesser extent regulatory bodies with oversight of commercial insurers. There is little or no attention to social forms of insurance in the context of anthropogenic climate change. The CASs approach adopted in this thesis, *i.e.* insurance as a system, and comprising social and commercial elements, is novel.

The literature on commercial insurance (*i.e.* the insurance industry) and anthropogenic climate change comprises two main bodies. One body conceives commercial insurers in political economic terms, for example with interests in the context of climate politics, or perhaps with the potential to play a role in global environmental governance (see Leggett 1993; Brown 1996; Leggett 1996; Gelbspan 1998; Newell and Paterson 1998; Sachs *et al.* 1998; Paterson 1999, 2001; Jagers and Stripple 2003; Jagers *et al.* 2005). This literature adopts a critical perspective[14] and is focussed on commercial insurers as a coherent, collective whole, with a particular political economic 'location' that is distinct from others in the international political economy, notably the fossil fuel sector. This literature concludes broadly that commercial insurers are unlikely to provide leadership on mitigation, as discussed in Chapter Four (paper B).

The other body is uncritical, and focuses on the socio-technical potential for commercial insurers to play a role in managing emerging climate risks. This literature generally includes more attention to diversity within commercial insurers, *i.e.* distinguishing between property and life insurance lines, and between insurers, reinsurers and regulators (Dlugolecki 1999; Crichton and Salt 2001;

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[14] As noted in Chapter Seven (paper E), The term *critical* 'is deeply perverse in the plurality of connotations and interpretations (some of them contradictory) it provokes' (Brookfield 2005, p.11). Critical political economy addresses questions of *why* effective mitigation is yet to be achieved (*e.g.* Paterson 2001), and also suggests limited opportunities and possibilities for achieving the necessary change (Levy and Newell 2002; 2005; Pearse and Stillwell 2008).

Mills 2005; Ross *et al.* 2007; Dlugolecki 2008; Dlugolecki 2009; Mills 2009). This literature generally concludes anthropogenic climate change represents (likely manageable) risks to insurers, and that there are limited opportunities for commercial insurers to profitably engage in adaptation and weak mitigation.

The socio-technical body of literature also asks what role the insurance industry might play in responding to anthropogenic climate change, and points to insurers' historical involvement in loss minimisation. Firstly, the classic example from the literature is insurers establishing and financing the first effective (private) fire brigades in the early eighteenth century (Dickson 1960, pp.62-7; Supple 1970, pp.95-8). 'Fire insurance offices themselves… attempt[ed] to safeguard those houses bearing each company's own firemark' (Clark 1999, p.2).

Secondly, commercial insurers have historically been heavily involved in research aimed at loss prevention. Kline (1964) for example discusses early involvement of American insurers in fire and building research before tracing insurer involvement in research focussed on industrial accidents and other areas. Mills *et al.* (2001) also refer to commercial insurers jointly financing research efforts, for example the Underwriters' Laboratories (Underwriters Laboratories 2010).[15] Mills *et al.* (2001) are careful to note, however, that commercial insurers' historical involvement in loss reduction has been local in focus: addressing a global and diffused challenge such as non-directly attributable anthropogenic climate change is unprecedented.

3.5 Conclusion

Chapter Three has introduced the literatures on anthropogenic climate change, the insurance system, and the relationship between the two, as relevant to this PhD. The reviews of all three areas are completed in subsequent chapters, as indicated. Paper A completes Chapter Three and contributes to the overall thesis through highlighting the continuing apparent intractability of anthropogenic climate change. Until such time as anthropogenic climate change is mitigated, it remains a threat to human societies generally and elements within human societies, specifically the insurance system.

[15] The Underwriters Laboratories (UL) (Underwriters Laboratories 2010) describes itself as 'an independent, not-for-profit product safety certification organization that has been testing products and writing Standards for Safety for over a century. UL evaluates more than 19,000 types of products, components, materials and systems annually'.

3.6 Introduction to paper A: What to make of COP 15?

This paper was invited by *Air Quality and Climate Change* and appeared in the immediate aftermath of the United Nations December 2009 anthropogenic climate change negotiations (the 15th Conference of the Parties, or 'COP 15') in Copenhagen. The paper was made possible through the author attending COP 15 as an observer. The paper argues that popular characterisation of COP 15 as a 'failure' is unjustified, and inconsistent with a fair assessment of the event's likely outcomes given the course of preparatory negotiations over the preceding two years. In contrast, the lack of constructive progress from the Copenhagen talks can be interpreted as a temporary reprieve of sorts: a binding agreement that formally committed states to anything other than rapid and deep cuts in greenhouse gas emissions would have locked in failure. As it stands, the possibility of effective and just anthropogenic climate change mitigation remains open. Nevertheless, the need for mitigation is urgent.

First conceived as a theoretical possibility, scientific consensus around anthropogenic climate change as a globally coherent phenomenon has strengthened to the point where scientific confidence is compelling. In the conservative words of the Intergovernmental Panel on Climate Change, warming of the climate system is 'unequivocal' (IPCC 2007b, p.5), that it is human-driven is 'extremely likely [likelihood >95%]' (IPCC 2007b, p.81), and '[m]ost of the observed increase in global average temperatures since the mid-20th century is very likely [likelihood >90%] due to the observed increase in anthropogenic greenhouse gas concentrations' (IPCC 2007b, p.10)

The course and outcome of the 15th Conference of the Parties is emblematic of the continuing intractability of anthropogenic climate change. Despite the two years of preparatory work and the two weeks of negotiations, no shared commitment to cut emissions rapidly and deeply was achieved.

3.7 Contribution of paper A in the context of the overall thesis

Table 3.1: Contribution of paper A in the context of the overall thesis.

Thick borders identify the research question to which paper A responds.

<table>
<tr><td>1</td><td colspan="2">Research aim: what does anthropogenic climate change mean for the insurance system?</td></tr>
<tr><td rowspan="2">1.a</td><td colspan="2">Research question: If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, i.e. is the threat temporary, intermittent, permanent, strategic, or existential?</td></tr>
<tr><td>Response:
• Permanent, strategic and possibly existential.</td><td>Locations:
• Chapter 3/paper A;
Chapter 4/paper B; and
Chapter 5/paper C.</td></tr>
<tr><td rowspan="2">1.b</td><td colspan="2">Research question: To what extent might anthropogenic climate change present an opportunity to the insurance system?</td></tr>
<tr><td colspan="2">Response locations:
• Chapter 4/paper B;
Chapter 5/paper C; and
Chapter 6/paper D.</td></tr>
<tr><td>2</td><td colspan="2">Research aim: how might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?</td></tr>
<tr><td rowspan="2">2.a</td><td colspan="2">Research question: How has the insurance system approached anthropogenic climate change to date?</td></tr>
<tr><td colspan="2">Response location:
• Chapter 4/paper B.</td></tr>
<tr><td rowspan="2">2.b</td><td colspan="2">Research question: If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?</td></tr>
<tr><td colspan="2">Response locations:
• Chapter 5/paper C; and
Chapter 6/paper D.</td></tr>
<tr><td>3</td><td colspan="2">Research aim: how might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?</td></tr>
<tr><td rowspan="2">3.a</td><td colspan="2">Research question: What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?</td></tr>
<tr><td colspan="2">Response location:
• Chapter 7/paper E.</td></tr>
<tr><td rowspan="2">3.b</td><td colspan="2">Research question: If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?</td></tr>
<tr><td colspan="2">Response location:
• Chapter 7/paper E.</td></tr>
</table>

3.8 Paper A: 'What to make of COP 15?: A ringside report'

Paper:

Phelan, L. 2010. What to make of COP 15? A ringside report. *Air Quality and Climate Change*. 44: 14-15.

What to make of COP 15? A ringside report

L. Phelan

Liam Phelan teaches in Geography & Environmental Studies at the University of Newcastle and is a PhD candidate at Macquarie University researching climate change and insurance systems. Email: Liam.Phelan@newcastle.edu.au. Here he makes some candid comments about COP 15.

The United Nations climate change negotiations (the 15th Conference of the Parties, or 'COP 15') in early December last year was an extraordinary event. This report is from the series of meetings that together constituted COP 15. The presence of more than 100 heads of states and governments in the last days – many at short notice, and most with substantial entourages and security requirements – together with around 34,000 participants overall, meant the meetings entailed at times overwhelming organizational challenges. This COP was significantly larger than any other, and certainly dwarfed the very early COPs, which drew no more than a couple of thousand participants.

Of around 22,000 observers in Copenhagen, I was one of only 300 lucky enough to have access for the whole two weeks. The price of access included no less than six different badges and passes, and hours of queuing across the two weeks to register, to simply enter the venue each day, and to then enter specific sessions. The price was worth paying: anthropogenic climate change is a globally coherent phenomenon that entails profound and unprecedented challenges to human societies. If we're to address climate change effectively and equitably, it will be through collective agreement and action. There is something of the miraculous in global-scale efforts we make to organise ourselves, as a species, to address this problem we've created.

THE ISSUE REMAINS OPEN

Premature reports from the dying hours of Copenhagen erroneously claimed agreement had been reached. This was lazy journalism, perhaps combined with the pressures of deadlines. As the hours dragged on and it became clear that agreement had in fact not been reached, subsequent reports described a situation in which agreement had 'unravelled'. This is also misleading. Two years of focussed work preceded Copenhagen. The Bali meeting in late 2007 produced the Bali 'roadmap' to guide negotiations through to Copenhagen. Yet by the time Copenhagen rolled around, on virtually all key issues, consensus had not been reached. Instead of coming together with broad agreement already achieved, and the freedom to dedicate the two weeks of meetings to hammer out complex details, negotiators struggled to find common ground on even basic issues. Being frank, no agreement at Copenhagen was always the more likely outcome. Given the direction the negotiations took at times, this is perhaps a good thing.

Across the two weeks the negotiations felt like a roller coaster, with rapid and frequent shifts in what appeared likely or even possible. Shifts in the direction of the negotiations were reflected in draft agreement texts of ad hoc working groups, circulated sometimes daily, with usually much of the text bracketed, indicating that much was yet to be agreed. The strong sense that no one was in control of either the process or outcome was a striking aspect of the meetings. An easy description of this outcome is that negotiators made no progress. However a more thoughtful analysis might be that the issue remains open. Climate change won't wait and time is short. As such, an ecologically effective and equitable result from Copenhagen would have been ideal. However a bad agreement would have locked in catastrophic failure. Mother Earth is forgiving but she does not negotiate: parties at climate negotiations can horse-trade with each other all they wish, but ultimately, the only realistic concessions to be made are between states and between peoples, not in favour of political expediency in denial of ecological reality. As I see it, no agreement at Copenhagen falls somewhere in between a good agreement and a bad agreement: things could have turned out better, but equally they could have turned out much worse.

FAULT LINES AND FAIRNESS

A key tension at the meetings was between the extraordinary pressure on parties to strike a deal on the one hand, and the profound lack of trust between the parties on the other. The more than 100 heads of states and governments didn't come to Copenhagen to walk away empty handed. But as became clear, neither did they all come ready to negotiate in good faith.

Both the United Nations Framework Convention on Climate Change, and the Kyoto Protocol, refer to "common but differentiated responsibilities" of states in relation to climate change. In short, this language acknowledges that whilst all states have a responsibility to mitigate climate change, states have contributed to creating the climate change problem to varying degrees, and have differing capacities to mitigate and adapt to climate change. Bluntly, industrialized countries have largely created the climate change problem by emitting the vast bulk of greenhouse gases in the course of industrialization since 1850, and have lived well and become rich doing so. Additionally, industrialized countries have the greatest capacity to mitigate and adapt. In contrast, low income countries have contributed least to climate change, have substantially less capacity to mitigate and adapt, and are therefore most vulnerable. Further, low income countries continue to struggle with challenges of poverty and underdevelopment.

This is all ancient history in a sense. Virtually all states agreed to this language previously: in 1992 in the Framework Convention on Climate Change (the UNFCCC), and again in 1997 in the Kyoto Protocol (which came into effect in 2005). The Kyoto Protocol is an instrument of the Framework Convention. Reflecting the principle of common but differentiated responsibilities, it specifies unilateral emissions reductions targets for industrialised countries, i.e. industrialised countries' emissions reductions independent of any reductions low income countries might make. The idea here is that industrialised countries will take the lead on climate change mitigation. The Kyoto Protocol's first commitment period specifies industrialized countries' binding commitments to emissions reductions through to 2012. Second and subsequent commitment periods are anticipated. For the past two years since Bali, states have adopted a two track approach to climate negotiations, with one track linked to the Kyoto Protocol and dedicated to this issue: what industrialised countries' emissions reductions targets will be in second and subsequent Kyoto commitment periods, i.e. from 2013 onwards.

Copenhagen was supposed to finalise industrialised states' emissions reductions commitments for a second and subsequent Kyoto commitment periods. Instead, industrialised countries came to Copenhagen with little to offer. Australia for example offered reductions not greater than 25% by 2020 (0n 1990 levels), where the science calls for reductions of at least 40%. And even this was dependent on the meeting achieving a global agreement. Other states disgraced themselves by suggesting dropping targets for 2020 altogether, in favour of targets for 2050 only. The idea that we

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might somehow achieve reductions in the order of 95% by 2050 without any interim targets is laughable.

More alarmingly, industrialised countries used the two weeks of meetings to try to walk away from earlier commitments to cut emissions. Instead industrialised countries attempted to make their emissions reductions contingent on mitigation action by low income countries.

Not that this is how the industrialized countries would describe their approach. The language of the negotiations is frequently arcane, and almost always inaccessible. To some extent this is to be expected: climate change mitigation is a multi-faceted and highly complex area. But the language is also used by parties both to frame debates in ways that suit some parties better than others, and to obscure intentions. For example, during the meetings Australia and others called for a "single, comprehensive agreement" out of Copenhagen, which at first blush sounds reasonable enough. But in the context of efforts to address climate change since 1992, the implications are profound, potentially undermining the important principle of common but differentiated responsibilities.

Australia's call for a "single, comprehensive agreement" was an attempt to shift discussion of unilateral industrialised country emissions reductions commitments out of the first negotiation track established at Bali and linked directly to the Kyoto Protocol. Instead, Australia wanted industrialised country emissions reductions targets discussed in the second negotiation track, also established at Bali, and linked directly to the Framework Convention. The second track is dedicated to longer-term cooperative action amongst all states, i.e. industrialised and low income countries. The second track allows amongst other things for negotiations around financial flows from industrialised countries to low income countries for climate change mitigation and also adaptation. There is also space in this track to discuss if and what fair emissions reductions commitments low income countries might begin to make.

One effect of moving negotiations around industrialised country emissions reductions commitments from the first to the second track would be treating emissions reductions of all states as though the historical and current situations of all states are comparable. This would undermine the previously established and agreed principle of common but differentiated responsibilities, and was described by some observers as threatening to be "the death of Kyoto". Low income countries stood firm and as the dust from Copenhagen settles, both the Kyoto Protocol and the two track negotiation framework remain.

The climate negotiations are wide-ranging, from emissions reductions targets to adaptation financing mechanisms, to carbon accounting and management of carbon sinks. So there are many other examples of bastardry across the two weeks. In this vein, things got off to a bad start: even before negotiations began, a draft agreement text being pushed by the conference chair Denmark, together with Australia, the UK and others, was leaked. As media reports at the time indicated, the content of the text was highly problematic for many parties, particularly low income countries, who also reacted furiously at being excluded from its drafting. Sneaky, secret text drafting was repeated through the meeting.

Some degree of dirty trickery is perhaps to be expected: climate change mitigation is an intractable issue and the future of our world as we know it is at stake. But in the absence of trust between parties, it's difficult to see how substantive agreement can be reached, let alone acted upon.

WE'RE IN IT TOGETHER WHETHER WE LIKE IT OR NOT

Whether we like it or not climate change requires a collective global response, including international binding agreements for deep and rapid cuts in emissions. It's easy enough to characterize the lack of an agreement from Copenhagen as a failure. On the other hand, an agreement that locked in failure would have been catastrophic. I suggest that the outcome from Copenhagen is that we live to fight another day. And that's a success of sorts.

Many smaller states were inspirational in the way they refused to be bullied into adopting positions that were clearly not in their interests. One example from our part of the world is Tuvalu standing up to Australia. Tuvalu came to Copenhagen with the objective of a global agreement to limit warming to 1.5°C, on the basis that this will allow Tuvalu's survival. In contrast, warming limited to 2°C – even if achieved – would mean likely oblivion for Tuvalu. Australia distinguished itself in the dying days of the meetings by attempting to pressure Tuvalu into dropping its commitment to a target of 1.5°C. In a media conference on the second last day, Tuvalu's Prime Minister declared Tuvalu would not be pressured by Australia into signing its own death sentence.

Climate change entails complex questions of science and technology. In the example above of what constitutes an appropriate level at which to limit warming, i.e. 1.5°C vs 2°C, science is central. The science also remains live: 2°C has previously been proposed as appropriate for avoiding the worst impacts of anthropogenic climate change. The policy world almost caught up at Copenhagen. But in the meantime, it has become clear that 1.5°C is a more prudent target, and one that only some states have grasped so far.

However, I suggest climate change is not most usefully dealt with primarily as a science question, as a technology question, as an environment question, or even as an economic question. Climate change is most usefully dealt with as a justice question: this is what makes it intractable. We need a response to climate change that is fair, ambitious and binding. Fairness is an important human value for which there is broad support. In purely pragmatic terms, we need a fair outcome to succeed: an effective outcome will be one to which all states agree: it's difficult to see states agreeing to a deal that is not fair, consistent with common but differentiated responsibilities. We need an ambitious response because climate change is such an enormous challenge: tinkering won't deliver survival. Lastly, we need a binding response in order to succeed. As difficult as reaching agreement might be, delivering on that agreement will be even harder. In the years and decades ahead, we'll need a binding basis for the necessary mitigation and adaptation action.

4. Ecological viability or liability?

4.1 Introduction

This chapter provides a novel critique of both insurance system responses to anthropogenic climate change and an attendant political economy perspective on the relationship between anthropogenic climate change and the insurance system. The chapter is based on paper B 'Ecological viability or liability?: Insurance system responses to climate risk'.

Anthropogenic climate change is a phenomenon of the Earth system, which is characterised by thresholds and non-linear change. The analysis in this chapter considers the adequacy of insurance (in its broadest sense) responses to changing climate risk. A complex adaptive systems (CASs) analysis suggests ecologically effective (*i.e.* strong) mitigation is the only viable approach to manage medium- and long-term anthropogenic climate change risk – for the insurance system itself and for human societies more widely. In contrast, insurance system responses to anthropogenic climate change to date are found to be extremely limited. Where discernible, even the most substantial insurance system responses are primarily adaptive or very weakly mitigative.

This analysis additionally extends an earlier political economy perspective (*e.g.* Paterson 2001) that explains the limitations to insurance system responses to anthropogenic climate change. However, this previous political economy perspective provides little guidance to the ecological implications of such responses.

Chapter Four contributes to the overall thesis by raising questions for the ongoing viability of the insurance system in the face of unmitigated anthropogenic climate change, and for the many aspects of human societies globally reliant on the insurance system as a primary financial risk governance tool. The chapter concludes by suggesting that applying a CASs approach may provide new insights that could prompt insurance system evolution in support of effective governance of anthropogenic climate change risks.

4.2 Contribution of paper B in the context of the overall thesis

Table 4.1: Contribution of paper B in the context of the overall thesis.

Thick borders identify the research questions to which paper B responds.

1	**Research aim: what does anthropogenic climate change mean for the insurance system?**	
1.a	Research question: If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, *i.e.* is the threat temporary, intermittent, permanent, strategic, or existential?	
	Response: • *Permanent, strategic and possibly existential.*	*Locations:* • *Chapter 3/paper A; Chapter 4/paper B; and Chapter 5/paper C.*
1.b	Research question: To what extent might anthropogenic climate change present an opportunity to the insurance system?	
	Responses: • *Limited and short-term if at all in the absence of effective mitigation. Ultimately anthropogenic climate change threatens the viability of the insurance system as currently structured.* • *In contrast anthropogenic climate change mitigation presents a theoretical opportunity to the insurance system.*	*Locations:* • *Chapter 4/paper B; Chapter 5/paper C; and* • *Chapter 6/paper D.*
2	**Research aim: how might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?**	
2.a	Research question: How has the insurance system approached anthropogenic climate change to date?	
	Response: • *Strongest insurance system responses to anthropogenic climate change to date are generally adaptive and weakly mitigative.*	*Location:* • *Chapter 4/paper B*
2.b	Research question: If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?	
	Response locations: • *Chapter 5/paper C; and Chapter 6/paper D.*	
3	**Research aim: how might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?**	
3.a	Research question: What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?	
	Response location: • *Chapter 7/paper E.*	
3.b	Research question: If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?	
	Response location: • *Chapter 7/paper E.*	

4.3 Paper B: 'Ecological viability or liability?: Insurance system responses to climate risk'

Paper:

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Ecological viability or liability?: Insurance system responses to climate risk

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[Received dates here]

Abstract

This paper provides a novel critique of both insurance system responses to climate change and an attendant political economy perspective on the relationship between insurance and climate change. Climate change is a phenomenon of the Earth system, which is characterised by thresholds and non-linear change. This analysis considers the adequacy of insurance (in its broadest sense) responses to climate risk. A complex adaptive systems (CAS) analysis suggests ecologically effective (i.e. strong) mitigation is the only viable approach to manage medium- and long-term climate risk – for the insurance system itself and for human societies more widely. In contrast we find even the most substantial insurance system responses to date are generally adaptive and weakly mitigative. This analysis extends an earlier political economy perspective that explains the limitations to insurance system responses to climate change, but provides little guidance to the ecological implications of such responses. As such this paper raises questions for the ongoing viability of the insurance system, and for the many aspects of human societies globally reliant on the insurance system as their primary risk governance tool. We suggest a CAS approach provides new insights which could prompt insurance system evolution in support of effective climate risk governance.

Keywords: Climate change; insurance system; climate risk governance; public policy; adaptation, mitigation.

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Ecological viability or liability?: Insurance system responses to climate risk

> Insurance is a means of constructing the promise of economic security in a precarious and uncertain world (Knights and Vurdubakis 1993, p.734).
>
> Insurers themselves have not understood the scale of the implications of global warming (Dlugolecki 2009a, p.1).

1. Introduction

Anthropogenic climate change presents a 'diabolical policy problem' (Garnaut 2008, p.xviii). The nature of the phenomenon and its impacts, combined with the characteristics and socio-economic role of insurance, invite questions about the potential impact of climate change on insurance. In turn, this raises questions about the potential for insurance to play a constructive role in climate change mitigation and adaptation (e.g. Leigh et al. 1998; Paterson 2001; Albrecht and Rapport 2002; Dlugolecki and Keykhah 2002; Crichton 2005; Mills 2005; Kunreuther and Michel-Kerjan 2007; Ross et al. 2007; Botzen and Van den Bergh 2008). Our specific interest is the potential for engaging the insurance system[1] – established to transfer and pool financial risk – in support of ecological sustainability: mitigating climate change by driving down atmospheric greenhouse gas levels by reducing emissions and by protecting surviving carbon sinks such as forests.

Our engagement is with insurance as a system (Phelan et al. 2010b). We conceptualise the insurance system at global scale, as a subsystem of the global economy. In turn the economy is embedded in the Earth system, by which we refer to the integrated social-ecological system that is planet Earth and all life on it, including humans and our societies. We focus on the relationships between each of the three systems. This perspective is similar to Lovelock's (2007) 'Gaia', which refers to 'the interconnectedness of the Earth system, including all its life forms' (p.156). The perspective is also consistent with Crutzen and Stoermer's 'anthropocene' (Crutzen and Stoermer 2000; Crutzen 2002), which conveys the sense of a co-evolutionary process engaging ecological and human-social systems at global scale.

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[1] We refer to 'insurance system' in the singular. Willard Gibbs, a pioneer of systems thinking, defined a system as 'any portion of the universe [including ourselves and everything we have created, such as social systems] which we choose to separate in thought from the rest of the universe for the purpose of considering and discussing the various changes which may occur within it under various conditions.' (Rukeyser 1964, p.445, see also p.235).

We purposely make our adoption of a systems perspective explicit because insurance invites a range of approaches. Denenberg (1963) for example refers to a:

> fourfold classification [of] insurance… as a business, a legal institution, a technique for averaging loss, and an instrument of social planning, [with] many faces and forms, which continue to confound simple classificatory schemes. (1963, p.323).

We use the term *insurance system* to bring focus to all of the participants and their relationships that together allow ongoing provision and use of financially viable insurance. Anthropogenic climate change represents a strategic threat to human societies generally, and specifically to the world's (in the broadest sense) insurance system. Climate change is not simply a partial, temporary or episodic threat to the insurance system's financial viability. The failure of the insurance system to respond appropriately to climate risk is sadly consistent with broader societal inability to resolve the climate crisis (e.g. Hamilton 2010).

The insurance system as we conceptualise it is defined in some detail in section two. Our approach varies from a narrower focus prevalent in the scholarly and grey literatures on the insurance *industry* as a whole, or some part of it.[2] In section two we also examine insurance system responses to date. We find the strongest of these are limited to being adaptive or weakly mitigative, as opposed to strongly mitigative. In section three we highlight elements of an international political economy (IPE) perspective on insurance system responses to climate change. This perspective explains limits to insurance system responses, but provides little insight on the implications of such responses for the ongoing viability of the insurance system, or for the elements of human societies dependent on the insurance system.

In section four we then consider the adequacy of current insurance system responses to climate change, as opposed to strongly mitigative responses, given that climate change is a phenomenon of the Earth system, characterised by non-linear change and thresholds. Our critique of the IPE perspective on the insurance system-climate change relationship is made on the same basis. We undertake an initial complex adaptive systems (CAS) analysis of the insurance

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[2] The literature on the insurance industry and climate change comprises two main bodies. One conceives the industry in political economic terms, for example with interests in the context of climate politics, or perhaps with potential to play a role in global environmental governance (see Leggett 1993; Brown 1996; Leggett 1996; Gelbspan 1998; Newell and Paterson 1998; Sachs et al. 1998; Paterson 1999, 2001; Jagers and Stripple 2003; Jagers et al. 2005). The other is uncritical, focuses on the socio-technical potential for insurers to play a role in managing emerging climate risks, and generally includes more attention to diversity within the industry, i.e. distinguishing between property and life insurance lines, and between insurers and reinsurers (see Crichton and Salt 2001; Dlugolecki and Keykhah 2002; Mills 2005; Kunreuther and Michel-Kerjan 2007; Dlugolecki 2008; Hecht 2008; Maynard 2008; Ward et al. 2008; Dlugolecki 2009b; Mills 2009).

system and climate change, and raise questions about the merit of the insurance system's adaptive and weakly mitigative responses. Complex adaptive systems, 'unlike the natural systems that environmental and earth sciences have traditionally addressed' are human-dominated systems which 'display learning, adaptation and complex non-linear feedbacks' (Finnigan 2003, p.xi). Systems thinking generally emphasises connectedness, context and feedback, and focuses on interactions, relationships and patterns (Kay 2008, p.7). Section five concludes the paper and discusses the proposition that a systems perspective may offer insights for a sound basis for viable insurance system governance of climate risk into the medium and longer term.

2. Insurance system responses to climate change: Adaptive and weakly mitigative

Responses to climate change originating in the insurance system vary from non-engagement through to detailed policy positions. The focus of this paper is on insurance system (as a subsystem of the global economy) responses that have engaged with climate change most substantially. At best, the insurance system's most substantive climate change action to date is limited to adaptive and weakly mitigative responses. We have reviewed primary sources, such as policy documents and position statements of actors in the insurance system. We have also drawn on others' perspectives on the relationship between insurance and climate change, which have centred on commercial elements of the insurance system (i.e. a part or the whole of the insurance industry).

2.1 The insurance system

Our conceptualisation of insurance as a system includes for-profit and mutual insurers, government providers of insurance, reinsurers, specialised service suppliers such as loss modellers and brokers, regulatory authorities and industry representative bodies. The term also includes the legal and institutional frameworks created and used to facilitate access to insurance. Investors in insurance companies as well as insurers' own substantial investments are also included. We approach the insurance system as a key subsystem of the global, carbon-based economy, acting as the economy's primary financial risk governance tool.

The global economy is the source of anthropogenic greenhouse gas emissions and attendant climate change risks. The insurance system, as with other subsystems of the carbon-based economy, is implicated in generating climate risks by virtue of its integral role in emissions-producing economic activity. Simultaneously, the insurance system is potentially well-placed to support ecologically effective mitigation efforts. By *ecologically effective* we mean mitigation designed to avoid dangerous climate change. Mitigating climate change requires rapid and deep cuts in greenhouse gas emissions and removing greenhouse gases from the atmosphere i.e. by conserving surviving carbon sinks. Industrialisation has produced a rise in atmospheric CO_2 concentrations from pre-industrial levels of 280ppm to current levels of ~ 389ppm (King 2009; Tans 2010) – and concentration levels continue to rise. In contrast, a drop in concentrations to at least 350ppm – and perhaps lower – is required (Hansen et al. 2008).

A definite financial value for the insurance system overall is elusive. Incomplete data is available for elements of the insurance system including both commercial and publicly-funded social insurance, suggesting the insurance system overall is a significant component of the global economic system. Here we draw on disparate data sources centring on (but not limited to) the year 2007 to provide a guide to the financial value of the insurance system.

Social insurance financing for health expenditure alone totalled US$1.2 trillion globally (in 2006) (WHO 2009). Other key areas of state-financed social insurance expenditure are unemployment benefits and age and disability pensions.[3] The modern welfare state, which includes forms of social insurance, is most developed in Europe, and some data and projections are available for European Union (EU) countries: unemployment benefit expenditure (for 2007) is projected at 0.85%[4] of EU GDP (Economic Policy Committee and DG ECFIN 2006, p.190), i.e. circa US$142 billion. Gross public pension expenditure (for 2010) is projected at 10.3%[5] of EU GDP (Economic Policy Committee and DG ECFIN 2006, p.71), i.e. US$1.8 trillion.

Focussing on commercial elements of the insurance system, insurance is the world's largest industry with US$4 trillion in yearly premium revenue (Swiss Re 2008a, p.33) and an additional US$1 trillion in annual investment income (Mills 2009, p.13), and therefore larger than the defence, oil, electricity generation or pharmaceutical industries. Many insurers and reinsurers are themselves global firms. Munich Re and Swiss Re for example, the two largest reinsurance firms globally wrote premiums in 2007 valued at US$30.3 billion and US$27.7 billion respectively (Standard & Poor's 2008, p.26).

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[3] The OECD (2007, pp.76-77) aggregates data on "public social spending" across OECD member states, accounting for around 20% of GDP across member states. The category includes benefits which "address one or more contingencies, such as low income, old age, unemployment and disability." This categorisation is larger than our interest and applies to OECD members (i.e. industrialised countries) only.

[4] Unemployment benefit spending projection for the EU25 group of countries. Combined GDP for the EU27 countries in 2007 totalled €12.3 trillion (European Union 2009) Currency figures converted using mid-2007 exchange rates.

[5] Figure for the EU25 group of countries (excluding Greece).

Despite its size, the insurance market's socio-economic penetration is extremely uneven. Whilst insurance premiums accounted for a significant 7.5% of global GDP in 2007 (Swiss Re 2008a, p.41), industrialised countries accounted for 90% of the global market (Swiss Re 2008a, p.33). Even as insurance markets are largest in industrialised economies, historically and currently the major source of anthropogenic greenhouse gas emissions, the majority of the world's population – in low income countries and most vulnerable to climate risk – is without access to either social or commercial elements of the insurance system.

On the basis of the above information, we conservatively suggest the value of the global insurance system (broadly defined) to be in excess of US$8 trillion (in 2007). This represents at least 15% of global GDP of US$54 trillion in 2007 (Swiss Re 2008a, p.8). As such the insurance system is a significant socio-economic subsystem of the global economy.

Climate change has moved toward centre stage for some actors in the insurance system over recent years but responses to climate change are uneven. Our focus is the more substantial insurance system responses which are found in only a small number of larger, more established insurers, reinsurers, and industry associations. The remainder of this section focuses on examples of those actions.

The Association of British Insurers declared in 2005 that '[c]limate change is a key issue for the world in the 21st century' (2005, p.3). A 2006 report, From Risk to Opportunity: How Insurers Can Proactively and Profitably Manage Climate Change opens with a number of quotations, including the following attributed jointly to Chief Risk Officers of nineteen major insurance houses:

> Climate change has the potential to develop into the greatest environmental challenge of the 21st century. The recent period of intense tropical cyclone activity most likely reflects the effects of both natural climate variability and a superimposed global warming trend due to human causes (Mills and Lecomte 2006, inside cover).

However it would appear insurance industry behaviour more generally belies the strong rhetoric above. Andrew Dlugolecki (2009b), with reference to Mills (2007a) notes that:

> Across the global insurance industry, activity on climate change is low. [A] recent survey identified just 190 organisations engaged in meaningful ways, from amongst the tens of thousands of underwriting and intermediary firms in existence. While this was double the number a year before, it is still tiny (2009b, p.17).

A more recent survey (Mills 2009) identifies an increase in the number of commercial insurance system actors firms engaging in climate activity, up to 224. Nevertheless Dlugolecki's point still stands. Given the variation in the above perspectives, insurance system responses to climate change warrant careful attention.

2.2 Adaptive responses

The potential role of insurance in adaptation to anthropogenic climate change remains an ongoing focus for both scholars and practitioners (e.g. Herweijer et al. 2009; Botzen et al. 2010). Since the mid-nineties some commercial insurance system actors have attempted to adapt to climate (and other) risks by shifting financial risk outside of the insurance system and onto capital markets via insurance-linked securities. Some in the insurance system have also attempted to make better use of forecasting extreme weather events. Paterson (2001; 2005) refers to both these strategies and we review them in some detail in section three below.

In more recent years some insurers have begun selling insurance products aimed at supporting those insured's adaptation to climate change (Mills 2007a; 2009). Hecht (2008) categorises these into two groups. The first is products that mitigate losses (as opposed to mitigate climate change, i.e., lead to reduced losses from insured events rather than a cut in greenhouse gas emissions). An example would be a reduced premium for hurricane insurance where the insured building meets specified standards. Some climate adaptation products may also incidentally support climate change mitigation efforts. The second is products that allow those insured to pass on some climate-implicated weather risks. An example is microinsurance programs (see Churchill 2006) being piloted in some rural communities in low income countries, to mitigate catastrophic weather event-related losses. The Munich Climate Initiative is an example of a such a program drawing on the understanding that 'insurance solutions can play a role in adaptation to climate change' (MCII 2010).

2.3 Weakly mitigative responses

We categorise weakly mitigative insurance system responses to climate change as (i) public policy-related research, lobbying and networking, (ii) support for corporate carbon disclosure initiatives, and (iii) insurance products that support limited reductions in policy holders' emissions, or that support other emissions reductions initiatives, for example investments in renewable energy projects perceived to be financially risky.

2.3.1 Public policy-related research, lobbying & networking

Research and analysis is an area where some actors in the insurance system have been comparatively proactive in relation to climate change mitigation: numbers of research reports have been released by major reinsurance houses on climate change-related material. For example Munich Re, Swiss Re and Lloyd's in recent years have produced and made accessible through their websites research materials including statistical records and analyses (Munich Re 2007; Lloyd's 2008; Swiss Re 2008b). The Association of British Insurers (2005) is another insurance system actor active in this regard.

In 2008 The Geneva Papers: Issues & Practice published a special issue on 'Insurance and Adaptation to Climate Change'. This is significant in itself, given the journal is a publication of The Geneva Association (2008), an association constituted of the Chief Executive Officers of the eighty largest commercial insurers globally. The focus on adaptation is certainly necessary given climate change impacts are already manifest. However mitigation received substantive attention in only three (Dlugolecki; Leblanc; Maynard) of the nine papers included in the issue.

Recent years have also seen a small flurry of insurance system public relations activity on climate change. For example, Allianz Group partnered with the World Wide Fund for Nature to produce the report, Climate Change & the Financial Sector: An Agenda for Action (Allianz and World Wildlife Federation 2005). Lloyd's 360° project (Lloyd's 2008) is another. The research output from a small number of insurers, reinsurers and representative associations, while commendable, is a far cry from strong mitigative action on climate change by the insurance system. This is surprising given the insurance system's core capacities in the risk and loss governance area, and long and rich history of active engagement in loss reduction activities (Mills and Lecomte 2006).

Some insurance system actors in recent years are beginning to demonstrate a greater commitment to networking and lobbying in support of changes to climate policy. Internationally, the establishment of the United Nations Environment Program Finance Initiative's Insurance Working Group (Dlugolecki 2007) and the Climate Change Working Group (CCWG 2007) are examples. In Australia two insurers – one domestic (Insurance Australia Group) and one international (Swiss Re) – joined in 2006 with other major corporations and an environment non-government organisation to establish the briefly active Australian Business Roundtable on Climate Change (ABRCC 2007). In both the UK and the US, representative associations are also beginning to focus on the implications of climate change for a functional insurance system.

2.3.2 Support for voluntary carbon reporting initiatives

A small number of insurance system actors including some insurance firms and investors in insurance firms, have participated in voluntary carbon disclosure initiatives such as the UK-based Carbon Disclosure Project (CDP), and the US-based Investor Network on Climate Risk (INCR). Both initiatives seek to use institutional investors' financial clout to encourage the large corporations in which they invest to monitor and report publicly on the climate impact of their businesses. The CDP in particular has been successful in encouraging a large proportion of the world's largest firms to participate, but the information reported has been of limited use for investors due to its variability from firm to firm, and also across reporting periods (Kolk et al. 2008). Further, with reference to the question of what impact – if any – reporting might have on behaviour, for firms in emissions-intensive sectors such as electricity generation, fossil fuels and mining, 'the trend shows increasing emissions' (Kolk et al. 2008, p.742).

Some insurance system actors have also committed to reduce their own emissions. This commitment applies to Swiss Re's operations, for example emissions generated through building and operating offices and business travel, and a preference for using suppliers that make similar commitments (Swiss Re 2008c). It does not include reference to Swiss Re's investments and falls well short of a substantial contribution to an ecologically effective response to climate change. Insurers' operational emissions are surely small in comparison to the emissions attributable to the substantial financial assets held by commercial elements of the insurance system – in the order of US$55 trillion (Dlugolecki 2007, p.10).

2.3.3 Products that support emissions reductions

Some actors in the insurance system provide products that facilitate the commercialisation of renewable energy technologies, which can avoid anticipated increases in greenhouse gas emissions, but which entail substantial financial and regulatory risks (Leblanc 2008). One example of a potentially effective support role is insurance system products that facilitate investment in renewable energy projects through the Clean Development Mechanism (CEM) and Joint Implementation (JI), under the Kyoto Protocol (see Mills and Lecomte 2006, pp.22-4). However the record of CDM and JI in reducing CO_2 emissions is extremely poor (Lohmann 2008). As such the potential for reducing emissions via this path is at present limited.

Some actors in the insurance system now offer products that support reductions in policy-holders' emissions (see Dlugolecki 2007, pp.40-7; and Mills 2009). One example is vehicle insurance premiums that are calculated in part based on distance travelled: the shorter the distance travelled in the insured period, the lower the premium, and the lower the emissions. However emissions reductions of this magnitude, although a positive innovation, are well short of the deep and rapid cuts required across the global economy to avoid dangerous anthropogenic climate change.

2.4 Effective governance of climate risk?

Effective climate change risk governance requires a rapid and fundamental shift away from the global economy's reliance on burning fossil fuels (Stern 2006; IPCC 2007a; Garnaut 2008). Societal responses to date are utterly inadequate, a point underscored by the course of climate negotiations in Copenhagen in December 2009 and the preceding two-year preparatory effort (Phelan 2010). Despite decades of policy discussion, design and implementation, global CO_2 emissions rates and atmospheric concentrations continue to rise well beyond (rather than reduce to within) biogeophysical limits: '… the acceleration of both CO_2 emissions and atmospheric accumulation [in the period 2000-2007] are unprecedented and most astonishing during a decade of intense international developments to address climate change' (Global Carbon Project 2008).

As the greenhouse gas levels in the atmosphere continue to increase so too do climate risks. Moreover, there is no reason to believe that the relationship is linear. On the contrary, many assessments point to the rapid approach of thresholds past which risk escalates rapidly (e.g. Schellnhuber et al. 2006). The effect of the insurance system's weakly mitigative efforts to date is negligible. In section three below we review a political economy perspective on the limitations of insurance system responses to climate change. Action by the insurance system is yet to lead to significant reductions in anthropogenic greenhouse gas emissions. On this basis we describe the insurance system's mitigative responses to climate change as generally weak.

3. Limits to insurance system responses to climate change: A political economy perspective

Recent limited insurance system responses to climate change are somewhat consistent with Paterson's (2001) earlier international political economy (IPE) perspective on the relationship between insurance and climate change. The IPE perspective is narrower than our systems approach and addresses the global insurance industry only, i.e. commercial elements of the insurance system. Paterson (2001) concludes that commercial elements of the insurance system have a limited commitment to a reduction in global greenhouse emissions, even though climate change had been acknowledged as a potential phenomenon – and one with implications for risk governance – by some in the insurance system at least as far back as the 1970s (e.g. Munich Re 1973).

The IPE perspective was generated in the context of expectations that the insurance system might provide a source of corporate leadership for climate change mitigation (see Newell and Paterson 1998; Paterson 1999). The bases for this proposition include insurance having a greater perceived vulnerability to climate change than other business sectors (a persistent perception - see for example Pinkse and Kolk 2009, p.93). Jeremy Leggett (1993), in work for Greenpeace International, proposed a three-part typology of potential strategic insurance sector approaches to global climate politics in the context increasing levels of climate risk.

> Leggett's belief was that while insurers might be tempted to go for the second of these [i.e. adaptation], they could be pushed from adopting the second towards the third [i.e. mitigation], arguing to insurers that when data cease to be actuarial, the second set of responses becomes inadequate (Paterson 2001, p.19).

The IPE perspective is detailed and we do not review it here.[6] We note only that the perspective reflects a linear understanding of the Earth system. Adaptive and weakly insurance system responses to climate change are consistent with a linear understanding of the Earth system, and we highlight two aspects of the IPE perspective below. The need for a non-linear understanding of the Earth system is the basis of our critique provided in section four of both insurance system responses to climate change and the attendant IPE perspective.

Paterson (2001) argues that the commercial element of the insurance system consider climate change a manageable threat in part because it has at its disposal two opportunities for limiting exposure to climate risk. The first assumes increased accuracy in climate system prediction: the potential for better prediction of extreme weather events over periods of twelve to eighteen months, roughly congruent with standard reinsurance contract periods. As such reinsurers (key actors in the insurance system) may be able to prospectively (i) increase premiums

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[6] We draw primarily on Jagers et al. (2005), Jagers and Stripple (2003), Paterson (1999), Newell and Paterson (1998), and particularly Paterson (2001) for the IPE perspective on the relationship between insurance and climate change.

or (ii) limit exposures to large claims, for example by declining cover in some years. The second assumes increased capacity to carry climate risk. Specifically, capital markets have the potential to provide an enlarged pool in which to spread financial risks, traditionally assumed exclusively by the insurance system. Insurance-linked securities (ILSs), such as catastrophe bonds, are financial instruments that allow climate risk to be shifted outside of the insurance system and onto capital markets (Cabral 1999; Tynes 2000; Guy Carpenter & Company LLC 2007).

In essence both options are adaptive responses to climate change that may contribute to commercial insurance elements of the insurance system continuing to operate without needing to engage in climate change mitigation. The IPE perspective suggests that in effect, armed with better information about the Earth system and a larger pool in which to spread financial risk, commercial insurers could remain profitable in the face of global ecological crisis: climate change could even be a business opportunity for insurers.

Our argument is not that adaptation is of no value but that adaptation measures rarely make a contribution to climate change mitigation. The strongly dominant emphasis on the potential for insurance to play a role in adaptation and weak mitigation (e.g. Barrieu and El Karoui 2002; Jagers and Stripple 2003; Mills 2003; Allianz and World Wildlife Federation 2005; Association of British Insurers 2005; Churchill 2006; Kunreuther and Michel-Kerjan 2007; Mills 2007b; Ross et al. 2007; Botzen and Van den Bergh 2008; Hecht 2008; Leblanc 2008; Lloyd's 2008; Swiss Re 2008b; Ward et al. 2008; CCRIF 2009; Mills 2009; MCII 2010) obscures what is uncontroversial in the contexts of climate science (e.g. IPCC 2007a) and international climate negotiations (e.g. United Nations 1992). Mitigation remains necessary. A successful mitigation response is inconceivable without the engagement of insurance – and all other socio-economic subsystems. In section four below we argue ecologically effective mitigation in the short-term is necessary for viable societal governance of climate risk in the medium- and long-term.

4. Mitigation as effective climate risk governance: A systems perspective

Mitigation is essential for human societies generally to avoid dangerous anthropogenic climate change (IPCC 2007b). In late 2008, after the Presidential election in the United States and before the inauguration of President Obama, leading climate scientist James Hansen and his wife Anniek wrote an open letter to Barack and Michelle Obama, 'as fellow parents concerned about the Earth that will be inherited by our children, grandchildren, and those yet to be born.' In their letter the Hansens urged the need for effective action on climate change, saying that

> There is a profound disconnect between actions that policy circles are considering and what the science demands for preservation of the planet... Science and policy cannot be divorced. It is still feasible to avert climate disasters, but only if policies are consistent with what science indicates to be required (Hansen and Hansen 2008).

In this section we introduce a complex adaptive systems perspective to demonstrate why adaptation to climate change in the absence of ecologically effective mitigation is not a viable strategy for the insurance system. The IPE analysis suggests commercial elements at least of the insurance system have access to two potentially viable climate change adaptation strategies. Below we review each proposed adaptation strategy and argue both are unrealistic. Considering the adaptation strategies' flaws is helpful for explaining why adaptation without mitigation is not a viable strategy for the insurance system, or for the human societies dependent on the insurance system for effective risk governance. The critique is also helpful for identifying limitations of the IPE perspective on the insurance system-climate change relationship.

The Earth system is a complex system, characterised by thresholds and non-linear change (Schellnhuber et al. 2006). The Earth system changes over space and time in response to multiple influencing factors, such as massive increases in atmospheric concentrations of CO_2 emissions (Keller et al. 2007). Complex systems such as the Earth system differ from simple, static systems, such as motors and computers, in that they are self-organising and embody a degree of uncertainty as they experience transformation processes. One of the features of complex systems is their capacity for surprise (Schneider 2004). Sometimes complex systems change their structures fundamentally and apparently suddenly. Apparently sudden change in these systems can occur in response to the cumulative impacts of influences that are not readily perceived and yet may have been building up over a long period (Keller et al. 2007; Lenton et al. 2008).

4.1 Adaptation option #1: Better information about the Earth system

This proposed adaptation option, part of the IPE perspective on the insuarncey system-climate change relationship, was made with reference to extreme weather events and relies on those in the insurance system attaining a markedly more precise understanding of the Earth system. This is unlikely to eventuate. The following three examples of extreme weather event research highlight the limitations of prediction in a complex adaptive system such as the Earth. First, some have suggested that '[a]fter accounting for changes in population and wealth… changes in extreme weather events [globally] may be responsible for a growth in losses by about 2 per cent a year since the 1970s' (and see Muir-Wood et al. 2006; Ward et al. 2008, p.134). The trend 'corresponds with a period of rising global temperatures' (Muir-Wood et al. 2006, p.188). Second, increased probability of hurricane intensity in some areas of the Earth's surface was predicted by some climate scientists and has been observed (Henderson-Sellers et al. 1998; Webster et al. 2005). Third, Knutson et al. (2010), also with reference to links between climate change and hurricanes, find that

> it remains uncertain whether past changes in tropical cyclone activity have exceeded the variability expected from natural causes. However, future projections based on theory and high-resolution dynamical models consistently indicate that greenhouse warming will cause the globally averaged intensity of tropical cyclones to shift towards stronger storms, with intensity increases of 2–11% by 2100 (Knutson et al. 2010, p.157).

Our argument in response to the better scientific information adaptive approach for insurers is fundamental: meaningful prediction in a period of climatic change is theoretically impossible due to the Earth system being a non-equilibrium system, characterised by non-linear change. By *meaningful prediction* we mean prediction accurate enough, at useful spatial and temporal scales, that would allow insurers to pre-emptively adjust premiums, and in extreme cases decline to issue cover. In contrast, weather prediction over the short term such as a few days, is possible but not helpful in avoiding climate risk.

Even if meaningful climate prediction were possible, varying premiums and declining to issue cover are complicated matters. With regard to social insurance, government simply denying insurance protection to vulnerable populations is politically untenable. With regard to commercial insurance, the industry is generally heavily regulated, and regulation can and does extend to forcing provision of cover and controlling price.[7] Even so, commercial insurers' existence is dependent on their ongoing financial viability. Aside from important practicalities of providing or denying access to insurance is a deeper question about the purpose of insurance. Insurance provides stability; flipping between providing and denying insurance because of rapid and significant changes in risk may undermine societal faith in the insurance system's products and providers, and therefore the insurance system overall.

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[7] Examples include statutory provision of compulsory automotive third party and workers' compensation insurance.

Climate change is shifting the Earth system into an alternative state where the Earth system is no longer as reliable as it was. Under such circumstances, historical data describing climate is rendered non-indicative of probabilities for future extreme weather events. Operational concepts such as 'one in a one hundred year flood', which are grounded in reliable probabilities observed and recorded over time, lose their usefulness.

Whilst Hurricane Katrina and its aftermath, particularly the manifestly inadequate emergency response, made headlines because of resulting social, economic and ecological impacts, another hurricane with a similar name a year earlier was more remarkable in a climate science sense. Hurricane Catarina hit the coast of Brazil in March 2004. Catarina was the first ever recorded hurricane to form in the South Atlantic (Pezza and Simmonds 2005). Hurricane Catarina was a surprise and, unlike other hurricanes was only named posthumously and informally, after the Santa Catarina region of Brazil where it made land (Henson 2005). Not only was Catarina not predicted, before it occurred it was considered inconceivable from a scientific perspective.

Beyond single weather events, changes in the Earth system are also visible in the aggregate of climate-linked disaster events. For example the 1980s saw on average 400 Earth system (or 'natural') disaster events globally. This increased in the 1990s to an average of 630 each year, and to 730 in the last ten years. Catastrophic Earth system events in 2007 totalled 960, the highest number since systematic recording began in 1980. Of these events 91% were climate-linked (IAIS 2008a, pp.15-6).

The Earth system is intrinsically unpredictable. Human endeavours – including the evolution of the insurance system – succeeded because of Earth system stability: past experience provided a reasonable guide for future experience. However a changing climate renders the Earth system unstable and characterised by unpredictable change (Roe and Baker 2007). Albrecht and Rapport, considering sustainability overall, argue that:

> the world of relative predictability, with respect to reliability of ecosystem functions, has by degrees been transposed to a world of relative chaos in which surprise dominates, often with severe human consequences (Albrecht and Rapport 2002).

Needless to say, the implications are profound for human societies generally, not simply the insurance system. Changes in Earth systems are better understood as thresholds that are crossed, rather than as linear, orderly and progressive change (Lenton et al. 2008). Increasing rates of change in elements of the Earth system – continually in advance of predicted rates – are a feature of climate change as currently manifest, and are examples of non-linear and faster-than-predicted change. Such elements demonstrating faster-than-predicted rates of change over recent years include the Greenland ice sheet melt and sea level rise (Oppenhiemer and Alley 2005, p.258; Rahmstorf et al. 2007). The science is not well enough developed to provide certain prediction – or even detection – of these and other Earth system thresholds before they are crossed (Keller et al. 2008; Lenton et al. 2008). Some thresholds have already been crossed; others still lie ahead.

The extent to which the Earth system is moving generally into a period of greater unpredictability is uncertain. The manner in which the impacts of climate change will be distributed geographically across regions and across economic sectors poses difficult questions for scientists:

> Until and unless major oscillations in the Earth System (El Nino-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO) and Atlantic Multidecadal Oscillation (AMO) etc.) can be predicted to the extent that they are predictable, regional climate is not a well defined problem. It may never be (Anonymous in Henderson-Sellers 2008).

Focusing on insurance, a key question is what the impact of greater unpredictability might be on societal capacity to maintain a viable insurance system; and if so, what forms the insurance system might take.

Additional to the theoretical impossibility of meaningful prediction are currently insurmountable practical considerations. Climate modelling at the level of spatial and temporal detail required for local planning or decision-making is not possible at present and unlikely to be possible in the near future. This is a practical rather than theoretical challenge, but significant nonetheless. The scale of models is currently too obtuse and increasing model resolution adequately is a significant technical challenge that is unlikely to be resolved in the near future (see Heffernan 2008; Nature 2008).

4.2 Adaptation option #2: Spread financial risk across the global economy

The search for greater capacity to assume risk has led to the spreading of financial risk outside of the insurance system and into capital markets through catastrophe bonds and other financial instruments collectively known as Insurance-Linked Securities (ILSs). The second adaptation option suggested in the course of the IPE perspective on the insurance system-climate change relationship relies on a change in the relationship between the insurance system and the global economy, i.e., shifting financial risk more directly, and in larger quantity, to the global economy. In practice, the use of such bonds remains limited but is growing to the extent that some actors in the insurance system are beginning to suggest the 'convergence' of the reinsurance and capital markets may become a long-term trend (Benfield Group Limited 2008, p.6; Magarelli and Harrison 2008). However our argument here extends beyond current practice and anticipated trends to what is theoretically possible – and impossible.

Spreading or transferring risk doesn't eliminate risk, it simply shifts it. From a systems perspective, shifting risk up a system scale from the insurance system to larger global capital markets may well provide a temporary increase in the capacity of an individual firm – or even the system as a whole - to bear financial risk. Longer term however, this shift invites larger-scale consequences in the event of (now larger) system failure. The apparent increased resilience of the insurance system to climate risk is achieved without attention to the cause of climate risk, and at the expense of the resilience of the larger system. Meanwhile, in the absence of ecologically effective mitigation, climate risks continue to increase.

Climate change is a globally coherent phenomenon. Whilst capital markets clearly have greater financial capacity than commercial elements of the insurance system to assume climate risk, capital markets too are part of the global economy, and thus also vulnerable to climate change as a function of the relationship between the global economy and the Earth system on which it is founded. Accordingly, if climate change is not effectively mitigated, in essence this strategy remains a temporary adaptation strategy and does three things.

First, whilst not addressing the problem directly, this strategy may buy an unspecified, and unknowable, amount of time which may or may not be used to pursue more strategic (i.e. mitigation-focussed) responses. Second, by shifting system risk up a scale, this strategy invites system failure at larger scale. Third, the adaptation strategy opens up the insurance system to new potential vulnerabilities grounded in the relationship between the insurance system and the global economy. The 2008 global financial crisis is one example. Even though the world's largest insurer required bailing out by the US Government (Federal Reserve Bank of New York 2008), to date the insurance system overall has not failed as a result of the financial crisis. However the potential for failure due to integration of insurance and financial markets through ILSs has attracted attention and motivated insurance regulators to make public announcements noting the resilience and stability of commercial elements of the insurance system in spite of linkages to financial markets (IAIS 2008b).

Threatened and actual collapses of insurance firms are profound events and reverberate throughout financial and public administration systems, and societies more broadly. The collapse of HIH Insurance in Australia in 2001 (McIlveen 2001; Commonwealth of Australia (HIH Royal Commission) and Owen 2003) is a prime example.

4.3 Sea level rise: A climate risk case study

Current and anticipated changes in sea level illustrate the non-viability of the adaptive strategies for the insurance system critiqued above. Sea level rise is an Earth system phenomenon which differs from extreme weather events and other Earth system risks in key ways. First, it manifests globally and simultaneously, thus the spatial scale is larger.[8] Second, it is effectively an irreversible change, where irreversible means a change likely to last 'at least 1,000 years' (Solomon et al. 2009, p.1704), thus the temporal scale impact is larger. Scientific certainty has solidified on the reality of anthropogenic climate change (IPCC 2007a). Yet great uncertainty of the timing and magnitude of impacts remains, including estimated rise in oceans over the course of this century. Rises in sea level are non-linear phenomena (Hansen 2007) for which information will remain incomplete, significantly around the rate of melting of the Greenland and West Antarctic ice shelves, leaving open the possibility that the rise over the current century may be much higher. The 2007 Intergovernmental Panel on Climate Change report leans towards 20-43cm (its mid-range projection), but acknowledges this projection is made 'excluding future rapid dynamical changes in ice flow' (IPCC 2007a, p.45). Leading climate scientists have made the point that the IPCC's Fourth Assessment Report projections are highly conservative (see Kerr 2007; Henderson-Sellers 2008). Others in the scientific community argue that over the coming decades changes in the melt of the ice sheets will be the major contributors to changes in sea level. James Hansen, noting the IPCC's caveat on sea level rise predictions, argues that on the basis of existing evidence of non-linear change, business-as-usual climate change will result in sea level changes manifesting much more rapidly, yielding 'a sea level change of the order of meters on the century timescale' (Hansen 2007, p.4).

Uncertainty and unpredictability around the timing of global sea level rise presents a significant challenge to the insurance system. The stability of both the Greenland and the West Antarctic ice shelves is a major unknown, and advances in modelling are unlikely to provide more accurate information before being overtaken by physical melting. Steven Schneider made the point back in the 1970s that climate change would require action before climate models could provide policy-makers with certainty (1976, pp.94-6, 148-9, 189-90, 329-30). Recent research

[8] Sea-level rise is a global phenomenon but not uniform (Nicholls and Cazenave 2010).

(Roe and Baker 2007) notes that 'uncertainties in projections of future climate change have not lessened substantially in past decades' (p.629), and argues that the persistent level of uncertainty 'is an inevitable consequence of a system in which the net feedbacks are substantially positive' (see also Allen and Frame 2007; p.631).

Accordingly, generating and making use of better information about climate change risk is not a viable long-term adaptive response for the insurance system. Spreading financial risk to capital markets is also not a viable adaptive response to impacts such as sea level rise. Many of the globe's major financial centres such as New York, Tokyo, Shanghai and London are physically threatened by sea level rise. Ten percent of the human population and thirteen percent of the urban population globally live in Low Elevation Coastal Zones, defined as 'the contiguous area along the coast that is less than 10 metres above sea level' (McGranahan et al. 2007, p.17). This raises several challenges for the insurance system. First, the financial scale of the risk is huge. Second, the risk to varied geographic locations is correlated. Third, and with a systems perspective in mind, the magnitude of sea level rise challenges directly both the insurance system and the global economy in which the insurance system is contained.

Sea level rise is a significant threat but not the only threat. Climate change is implicated in changed timing, duration, frequency, intensity and location of all weather events and climatic trends including cyclones, hailstorms, bushfires, droughts and floods (see Allen et al. 2007). Many less dramatic, longer term changes in currently insurable circumstances such as changes to agricultural conditions and tourist seasons also manifest as economic threats (for example Steffen et al. 2006; Agrawala 2007). The insurance system is vulnerable to such risks, as are human societies generally.

4.4 Limits to adaptation and to the political economy perspective

Anthropogenic climate change represents a strategic threat to the global insurance system, rather than being limited to a partial, temporary or episodic threat to financial viability to elements within it. In this situation adaptive and weakly mitigative actions are insufficient responses to climate change: the unpredictability and scale of the phenomenon means climate change threatens the very existence of the insurance system as currently structured.

The failure of the insurance system to respond appropriately to climate risk is consistent with broader societal inability to resolve the climate crisis. However the insurance system's failure is notable to the extent that insurance is a primary risk governance instrument of industrialised economies and societies. Adaptive and weakly mitigative responses to climate change, as opposed to strongly mitigative responses, are consistent with the assumption that climate change can be adapted to. The IPE perspective also implies adaptive actions without mitigation may constitute viable insurance system responses to climate change. A complex adaptive systems (CAS) analysis of the Earth system suggests this assumption is without basis. CAS analysis raises questions about the value of the insurance system's adaptive and weakly mitigative responses to climate change, with implications for both the ongoing viability of the insurance system specifically, and more broadly the human societies reliant on the insurance system for risk governance.

The implications for contemporary societies and their economies are also profound: the insurance system is the primary risk governance tool of industrialised societies. However failure of the insurance system does not mean the end of human civilisation: as noted earlier, the majority of the world's population survives without direct access to the insurance system. However it does signal massive changes in the scale and nature of the broader socio-economic system as currently constituted. As noted earlier, the threatened or actual failure of a single actor in the insurance system – such as a commercial insurer – can reverberate through a society. Accordingly, the wholesale failure of the insurance system overall implies major social upheaval.

Social learning (Folke et al. 2005; Keen et al. 2005) allows the possibility of constructive, iterative societal responses to a threatened or actual failure of the insurance system as currently constituted. Elsewhere a non-linear basis for insurance has been theorised (Phelan et al. forthcoming) and an insurance basis for carbon prices as a viable insurance system contribution to ecologically effective climate change mitigation has been proposed (Phelan et al. 2010a). Even so, insurance has a long history (Trennery 1926; Pfeffer and Klock 1974), and one grounded in a linear understanding of the Earth system, reflected for example in established probabilities for weather events and climate trends. The linear understanding was appropriate for those pre-climate change times. A necessary shift to non-linear basis for insurance requires a profound rethinking of the relationship between the insurance system and the Earth system.

5. Conclusion: A role for the insurance system in effective climate risk governance

The insurance system is contemporary industrialised society's primary risk governance tool. A complex adaptive systems analysis suggests climate change undermines the basis of the insurance system, i.e. the capacity to pool and spread financial risk on the basis of known probabilities. One possible conclusion from this is the ongoing viability of the insurance system is dependent on successful climate change mitigation in the form of dramatic reductions in CO_2 emissions and protection of surviving carbon sinks such as forests. Whilst a succession of adaptive measures can increase system capacity to manage financial risk in the short term, in the absence of ecologically effective mitigation, they sow the seed of larger-scale system failure later.

A systems approach highlights the linkages between the insurance system, the global economy and the Earth system, with one embedded in the next. The Earth system is complex and adaptive, characterised by non-linear change, and therefore inherently unpredictable. It was always thus. Changing the climate means pushing the Earth system outside of the stable state on which human social systems have been reliant.

A complex adaptive systems approach to the relationship between climate change and the insurance system promises a more comprehensive understanding of cross-system interaction, and thus perhaps a better account of the threat climate change presents the insurance system. A systems approach may also guide new policy responses to engage the insurance system in effective climate change mitigation.

We argue there may be potential for gearing the insurance system in support of effective climate change mitigation. However even the strongest current insurance system responses to climate change are adaptive and weakly mitigative as opposed to strongly mitigative. We suggest transdisciplinary research (Somerville and Rapport 2000; Albrecht et al. 2001, pp.72-73) anchored in a complex adaptive systems approach (Holling 2001; Scheffer and Westley 2007) may usefully complement and extend on the insights provided by the IPE account of inaction by elements of the insurance system. This approach would: explore the relationship between the Earth system, the global economy, and the insurance system; consider the threat that climate change presents the insurance system; and investigate the potential for insurance system responses geared towards mitigation.

Climate change is a globally coherent phenomenon of unprecedented magnitude. Shifting from the current carbon basis of the global economy implies socio-economic change on an unprecedented scale. Ecologically effective mitigation requires the engagement of the insurance system, together with all other subsystems of human societies. At a policy level, we suggest that consistent with the systems approach, and recognising the inadequacy of insurance system responses to date, effective insurance system governance of climate risk will require engagement of all participants in the insurance system, including policy makers, and providers of social and commercial forms of insurance.

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5. Reflexive mitigation and adaptation with grace

5.1 Introduction

This chapter is based on paper C 'Reflexive mitigation of the Earth's economy: A viable strategy for insurance systems'. The chapter applies a complex adaptive systems approach to the insurance system, the global economy, the Earth system, and the relationships among them. In so doing, this chapter demonstrates the value of a complex adaptive systems analysis of the anthropogenic climate change-insurance system relationship.

This chapter contributes to the overall thesis in several ways. The chapter reveals the implications of applying the CASs approach, *i.e.* the analysis concludes that strong mitigation is likely to be the only viable strategic response to anthropogenic climate change for insurance systems. The chapter also articulates a theoretical transition of the insurance system from a linear to a non-linear basis, consistent with the character of the Earth system. Importantly, this chapter introduces two new concepts: reflexive mitigation and adaptation with grace.

Reflexive mitigation is an adaptive approach to mitigating anthropogenic climate change recognising: (i) atmospheric carbon dioxide equivalent (CO_2e) emissions consistent with achieving and maintaining Earth system stability will vary over time in response to changes in the Earth system and the global economy, and in the relationship between them; and (ii) relationships between the Earth system, the economy and the insurance system are evolving, and therefore understanding of them is necessarily incomplete. Adaptation with grace is effective adaptation undertaken in an orderly and planned manner, embodying important principles of justice and equity, and with some expectation of longevity. The chapter argues successful insurance system adaptation to anthropogenic climate change – adaptation with grace – depends on returning the climate to a stable, familiar and relatively predictable state: effective mitigation is therefore a necessary precondition for successful longer-term insurance system adaptation.

The complex adaptive systems (CASs) approach applied here focuses on interactions among the Earth system, the global carbon economy and the insurance system. The CASs approach deployed in this chapter extends beyond the political economy perspective on the anthropogenic climate change-insurance system relationship discussed in Chapter Four (paper B) to better account for the risk anthropogenic climate change presents to insurance systems and to human-social systems more generally.

5.2 Contribution of paper C in the context of the overall thesis

Table 5.1: Contribution of paper C in the context of the overall thesis

Thick borders identify the research questions to which paper C responds.

<table>
<tr><td>1</td><td colspan="2">Research aim: what does anthropogenic climate change mean for the insurance system?</td></tr>
<tr><td rowspan="2">1.a</td><td colspan="2">Research question: If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, i.e. is the threat temporary, intermittent, permanent, strategic, or existential?</td></tr>
<tr><td>Response:
• Permanent, strategic and possibly existential.</td><td>Locations:
• Chapter 3/paper A; Chapter 4/paper B; and Chapter 5/paper C.</td></tr>
<tr><td rowspan="2">1.b</td><td colspan="2">Research question: To what extent might anthropogenic climate change present an opportunity to the insurance system?</td></tr>
<tr><td>Responses:
• Limited and short-term if at all in the absence of effective mitigation. Ultimately anthropogenic climate change threatens the viability of the insurance system as currently structured.
• In contrast anthropogenic climate change mitigation presents a theoretical opportunity to the insurance system.</td><td>Locations:
• Chapter 4/paper B; Chapter 5/paper C; and
• Chapter 6/paper D.</td></tr>
<tr><td>2</td><td colspan="2">Research aim: how might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?</td></tr>
<tr><td rowspan="2">2.a</td><td colspan="2">Research question: How has the insurance system approached anthropogenic climate change to date?</td></tr>
<tr><td>Response:
• Strongest insurance system responses to anthropogenic climate change to date are generally adaptive and weakly mitigative.</td><td>Location:
• Chapter 4/paper B</td></tr>
<tr><td rowspan="2">2.b</td><td colspan="2">Research question: If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?</td></tr>
<tr><td colspan="2">Response locations:
• Chapter 5/paper C; and Chapter 6/paper D.</td></tr>
<tr><td>3</td><td colspan="2">Research aim: how might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?</td></tr>
<tr><td rowspan="2">3.a</td><td colspan="2">Research question: What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?</td></tr>
<tr><td colspan="2">Response location:
• Chapter 7/paper E.</td></tr>
<tr><td rowspan="2">3.b</td><td colspan="2">Research question: If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?</td></tr>
<tr><td colspan="2">Response location:
• Chapter 7/paper E.</td></tr>
</table>

5.3 Paper C: 'Reflexive mitigation of the Earth's economy: A viable strategy for insurance systems'

Paper:

Phelan, L., Henderson-Sellers, A. & Taplin, R. 2010. Reflexive mitigation of the Earth's economy: A viable strategy for insurance systems. In W. Leal Filho (Ed.). *The Economic, Social and Political Elements of Climate Change*. Berlin, Springer Verlag. ISBN: 978 3 642 14775 3. In press.

Reflexive mitigation of the Earth's economy:
A viable strategy for insurance systems

Abstract

This paper proposes reflexive mitigation as an ecologically effective insurance system response to dangerous anthropogenic climate change. Reflexive mitigation is an adaptive approach to mitigating climate change recognising: (i) atmospheric carbon dioxide equivalent (CO_2e) concentrations consistent with Earth system stability will vary over time in response to changes in the Earth system and the global economy, and in the relationship between them; and (ii) relationships between the Earth system, the economy and the insurance system are evolving, and therefore understanding of them is necessarily incomplete. The paper presents a complex adaptive systems approach to anthropogenic climate change and demonstrates that the Earth system, the global economy and the insurance system are connected social-ecological systems. Current insurance system responses to anthropogenic climate change are generally adaptive and weakly mitigative rather than strongly mitigative. The paper argues successful insurance system adaptation to anthropogenic climate change depends on returning the climate to a stable, familiar and relatively predictable state: effective mitigation is therefore a necessary precondition for successful longer-term insurance system adaptation.

Key words

Complex adaptive systems, social-ecological systems, insurance, climate change, reflexive mitigation, adaptation with grace, adaptive cycle.

Insurance systems and climate change

This paper is about effective mitigation of climate change, and about the role the insurance system might play in this. We argue that whilst adaptation is essential for human welfare, mitigation is a strategic response to climate change for human social systems generally, and for the insurance system specifically. Climate change mitigation measures are those aimed at avoiding dangerous anthropogenic climate change by: (i) significantly and rapidly reducing greenhouse gas emissions; and (ii) protecting surviving carbon sinks (United Nations 1992p.xi).

Insurance has been described as “society’s primary financial risk manager” (Hecht 2008, p.1959). Given the magnitude of the risks climate change presents human societies, the nature of insurance system responses are important. Beginning in the early nineteen-nineties, insurance was repeatedly characterised as the industry with most to lose in a climate changed world, and therefore the business sector most likely to take a lead on mitigation (Leggett 1993; Gelbspan 1998; Sachs *et al.* 1998). The characterisation of the industry as particularly vulnerable to climate change impacts persists, for example (Pinkse and Kolk 2009, p. 93). Yet insurance industry responses to climate change have emphasised adaptive and some weakly, rather than strongly, mitigative measures (Phelan *et al.* 2008; Phelan *et al.* forthcoming).

Adaptation to climate change is necessary because some climate change impacts are already manifest, others are imminent, and there is a warming commitment in the Earth system which implies further impacts (Hansen *et al.* 2005; Hansen *et al.* 2008). We describe adaptive responses as tactical as opposed to strategic insofar as they do not directly address the causes of the threat. Tactical measures can also support strategic action: for example adaptation can ‘buy time,’ while strategic mitigation measures take effect. However there is very little time available: mitigating climate change requires fundamental change urgently (Richardson *et al.* 2009).

The paper adopts a complexity theory approach (Bradbury 2006; Waltner-Toews *et al.* 2008). The complexity approach highlights dynamism internal to systems as well as cross-scale interaction between systems. This theoretical perspective is useful for engaging with disequilibrium systems such as the Earth system, characterised by non-linear change and capacity for surprise (Schneider 2004). We characterise the global economy and insurance system also as complex adaptive systems. We conceptualise the insurance system broadly as comprising all the participants and their relationships that together allow ongoing provision and use of financially viable insurance. This includes for-profit and mutual insurers, government providers of insurance, reinsurers, specialised service suppliers such as loss modellers and brokers, regulatory authorities and industry representative bodies. This system also includes the legal and institutional frameworks created and used to facilitate access to insurance. Investors in insurance companies as well as insurers' substantial investments are also included (Phelan *et al.* forthcoming).

Relationships between the three systems are key to this analysis and are described in section two. Section three proposes a strong mitigation scenario for the insurance system and introduces two new concepts: reflexive mitigation and adaptation with grace. In contrast, section four critiques the insurance system's current adaptive and weakly mitigative approaches to climate change. Section five concludes the paper.

Linked social-ecological systems

Open social-ecological systems are complex adaptive systems comprising co-evolving human-social and ecological elements, and which interact with other social-ecological systems (Berkes and Folke 1998). A standard analytical approach to linked social-ecological systems describes smaller social-ecological systems as <u>nested</u> in larger social-ecological systems (Gunderson and Holling 2002). Our analysis focuses on the insurance system embedded in the global economy, in turn nested in the foundational Earth system, the largest social-ecological system. The emphasis on system dynamism and cross-scale, inter-system interaction: (i) highlights phenomena which result from cross-scale interaction (i.e. carbon emissions from the global economy impacting the state of the Earth system, as well as opportunities to effect change in the relationship between the insurance system and the economy); and (ii) is conducive to exploring opportunities for making changes in one system in order to drive changes in another system.

Complexity theory is still in its infancy and "tends to employ an eclectic collection of theories and methodologies designed to deepen our limited understanding of the properties of complex adaptive systems" (Finnigan 2006). Complex adaptive systems (CASs) approaches have been applied in a range of disciplines (Hartvigsen *et al.* 1998; Milne 1998; Anderson *et al.* 2005). CAS approaches to social-ecological systems are still very much in flux, and continuing to be advanced (Gallopín 2006; Janssen and Ostrom 2006; Walker *et al.* 2006).

CASs theory explains systems' capacity to adapt and evolve as well the inherent unpredictability characteristic of complex adaptive systems. A complexity approach is useful and appropriate for our study of the insurance system because it: (i) conceptualises integrated ecological and human social systems as social-ecological systems; (ii) uses clear and economical language to describe system dynamics and cross-scale interactions between systems; and (iii) supports multidisciplinary approaches to complex issues such as climate change. The theory accommodates the ambivalent role of the insurance system in dangerous anthropogenic climate change. Even as society looks to the insurance system for risk management, including management of climate risks, the insurance system simultaneously contributes to the creation of climate risks through the interconnectedness of the insurance system and the global economy.

Three systems…

Both Lovelock's 'Gaia' (Lovelock 2007) and Crutzen and Stoermer's 'anthropocene' (Crutzen and Stoermer 2000; Crutzen 2002) convey the sense of a co-evolutionary process engaging ecological and human-social systems at global scale. Increasing anthropogenic carbon dioxide equivalent (CO_2e) emissions causing changes in the Earth's climate, which in turn drive changes in human societies, is emblematic of the linked and co-evolutionary processes of ecological and human social systems at global scale. Earth system science and global environmental governance, originating in the natural and social sciences respectively, are research areas grounded in an understanding of the Earth system comprising intertwined ecological and human-social elements (Schellnhuber 1999; Steffen *et al.* 2003; Young *et al.* 2006; Biermann 2007).

The global economy has also been analysed as a complex adaptive system (Arthur *et al.* 1997; Beinhocker 2006). Beinhocker (2006) makes a detailed case for the superiority of complexity theory's explanation of economies as disequilibrium systems over orthodox equilibrium accounts. However whilst Beinhocker grounds his economic theory in physical reality, his thesis fails to connect with ecological reality, for example the notion of limits (e.g. Meadows and Club of Rome 1972; Meadows *et al.* 2004). In contrast Daly's earlier 'steady state economy' approach (1982) clearly recognises the social-ecological character of the economy, and in so doing makes the strong argument for a theoretical understanding of economy that recognises Earth system limits.

We use the term insurance 'system' and not 'industry' purposely to bring focus to all of the participants and their relationships that together allow ongoing provision and use of financially viable insurance. This explicitly includes welfare state-style social insurances such as universal health care, unemployment benefits and age and disability pensions. Also included are participants in what is more commonly understood to be the insurance industry such as for-profit and mutual insurers, government insurers, reinsurers, specialised service suppliers such as loss modellers and brokers, government regulatory authorities and industry representative bodies. Investors in insurance companies as well as insurers' substantial investments are also included. The term also includes the legal and institutional frameworks created and used to facilitate access to insurance (Phelan *et al.* forthcoming).

…in relationship

The conceptual approach to linked social-ecological systems is articulated graphically below. Figure 1 includes the Earth system, the global economy, and the insurance system, together with key cross-scale interactions relevant for this analysis. Indicative financial values are provided for the global economy and the insurance system to convey a comparative sense of scale. Values where indicated are generally for 2007, the most recent year for which disparate data is available, providing a systems 'snapshot' from that year.

The global economy is valued (in 2007) at ~US$54 trillion (Swiss Re 2008, p. 8). A definite figure for the value of the insurance system overall remains elusive: data is available for some elements of the insurance system including both the insurance industry and state-funded social insurance, suggesting that the value for the insurance system overall is large. For example, premiums – the major source of revenue for the insurance industry totalled US$4 trillion in 2007, and investment income generated an additional US$1 trillion for insurers (Swiss Re 2008; Mills 2009). Data for social insurance is even less comprehensive but what data is available underscores the magnitude of the insurance system. Health expenditure alone financed through social insurance totalled US$1.2 trillion globally (in 2006) (WHO 2009). Other key areas of state-financed social insurance expenditure are unemployment benefits and age and disability pensions (see OECD 2007, pp. 76-77). The modern welfare state, which includes forms of social insurance, is most developed in Europe, and some data and projections are available for European Union (EU) countries: unemployment benefit expenditure (for 2007) is projected at 0.85% of EU GDP (Economic Policy Committee and DG ECFIN 2006, p. 190), i.e. circa US$142 billion.[1] Gross public pension expenditure (for

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[1] Unemployment benefit spending projection for the EU25 group of countries. Combined GDP for the EU27 countries in 2007 totalled €12.3 trillion (European Union 2009) Currency figures converted using mid-2007 rates.

2010) is projected at 10.3% of EU GDP (Economic Policy Committee and DG ECFIN 2006, p. 71), [2] i.e. US$1.8 trillion. On the basis of the above information, limited sectorally and jurisdictionally, we conservatively suggest the value of the insurance system globally is at least US$8 trillion (in 2007), at least 15% of the global economy and as such a significant subsystem. In Figure 1 the Earth system remains unvalued in financial terms: for the purposes of our analysis it is sufficient to note the Earth system is without substitute and the existence of the other systems represented is wholly dependent on the Earth system (Daily 1997). The overall triangle shape of the figure with the Earth system placed at the base reflects this perspective.

Arrows between systems indicate cross-scale, inter-system relationships of interest for this analysis. Emissions from the global economy into the Earth system, and in return, future climate damages from the Earth system to the global economy are presented and valued in units of carbon emissions in 2007. Anthropogenic emissions are valued at 10 PgC, [3] comprising 8.5 PgC of emissions and 1.5 PgC of losses in surviving carbon sink capacity (Global Carbon Project 2008). Whilst the figure presents a static ‘snapshot’ from 2007, global emissions continue to increase and this is indicated by the upward-pointing arrow immediately following the emissions figure. In 2007 the Earth system sequestered 55% of anthropogenic emissions, leaving 4.5 PgC of emissions remaining in the atmosphere (Global Carbon Project 2008). In Figure 1 this is represented as 2007’s contribution to future climate damages returning to the global economy as changes to familiar and reliable weather and climatic conditions. Future climate damages will result from shocks such as extreme weather events, and stresses such as longer-term impacts such as changes in the location and viability of agricultural zones.

As total anthropogenic emissions continue to accumulate the Earth system’s efficiency in sequestering emissions is reducing (Global Carbon Project 2008). In combination with increasing emissions, this suggests an increasing rate over time of global emissions that remain unsequestered, indicated by upward-pointing arrow immediately following the emissions figure.

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[2] Figure for the EU25 group of countries (excluding Greece).

[3] 1 Pg (petagram) = 1 billion (or 1000 million) tonnes.

In Figure 1 the inter-system relationship between the global economy and the insurance system is dominated by a cycling of financial risk. The socio-economic function of the insurance system is to assume financial risk. The insurance system pools and transfers risks across the economy. Ultimately, the insurance system is wholly nested within the economy, and therefore financial risks, even when shifted via the insurance system, remain internal to the economy. Traditional examples include insurers' substantial investments (in the case of the insurance industry) and governments' treasuries (in the case of social insurance). More recently insurers have also begun to spread risk outside of the insurance system and onto capital markets through catastrophe bonds and other financial instruments collectively known as insurance-linked securities (Phelan *et al.* forthcoming). This allows access to the greater financial capacity of capital markets, and also demonstrates the cycling of financial risk between and across the insurance subsystem and the broader economy.

The focus of this paper is the theoretical potential for gearing the insurance system to drive or at least support cuts in anthropogenic emissions from the economy sufficiently rapidly and deeply to avoid dangerous climate change. In Figure 1 this system interaction is also located in the relationship between the insurance system and the economy and represented by the downward arrow.

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Figure 1 about here

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Why mitigation is a necessity for insurance systems

"Insurance is a means of constructing the promise of economic security in a precarious and uncertain world." (Knights and Vurdubakis 1993, p. 734). Yet the insurance system is an SES with significant human-social elements and not immune to the impact of anthropogenic climate change on Earth system stability. Fundamentally, financial risk in the global economy is manageable in the Earth system because of familiar system stability. Where the system remains in a familiar and stable state, past experience provides a reasonable guide for future experience. However a changing climate renders the Earth system unstable and characterised by unpredictable change (Schneider 2004).

On a timescale of interest to humans and our societies, the sum of climate change-related feedbacks in the Earth system is positive, i.e. climate change leads to feedbacks that reinforce rather than dampen changes in the climate (Allen and Frame 2007; Roe and Baker 2007). With warming, net positive feedback leads to further increases in warming so that climate pushes the Earth system further away from a familiar stable state to an alternate state which, whether stable or unstable, is unfamiliar. The non-linear quality of the change means the rate of the shift is continually increasing. Some aspects of non-linearity are reflected in recent predictions of the magnitude and timing of climate change impacts: in practice observed rates of climate change are repeatedly underestimated (Phelan *et al.* forthcoming). Additionally, Earth system thresholds means rates of change are uneven and unpredictable. Over time, increasing unpredictability tends to undermine the viability of the insurance system (Phelan *et al.* forthcoming).

Insurance responses to climate change to date are generally adaptive and weakly mitigative (Phelan *et al.* forthcoming). On the basis of a strictly linear understanding of insurance, adaptation measures appear as reasonable insurer responses to the threat of catastrophic losses. Adapting the insurance system to climate change allows greater capacity to take on risk short term. However, given the Earth system is a non-linear system, the long-term viability of adaptation strategies is limited (Hallegatte 2009). What appears to be an adaptation may in fact prove to be a maladaptation (Barnett and O'Neill 2010). In section three below we make a normative argument for the insurance system to pursue a strongly mitigative path. In contrast, section four describes the current adaptive and weakly mitigative trajectory of the insurance system with reference to climate change.

Reflexive mitigation: A viable insurance system approach

<u>Reflexive mitigation</u> offers the insurance system's an alternative to adaptive and weakly mitigative responses to climate change. In this section we apply a four-phase <u>adaptive cycle</u> (Holling and Gunderson 2002) used to represent the evolving state of social-ecological systems, to demonstrate change in the insurance system as it travels a reflexive mitigation path. The adaptive cycle has been developed as an heuristic to explain change processes in social-ecological systems.

In this section we make a normative argument: reflexive mitigation ought to be pursued by the insurance system because in contrast to adaptive and weakly mitigative approaches, it offers the potential for ongoing viability of the insurance system. Given broader human societal reliance upon the insurance system, the approach supports the insurance system to make a significant contribution to the sustainability of human-social systems more generally, consistent with insurance's role as society's primary risk manager. The section concludes with a brief note on the relationship between climate change mitigation and adaptation measures.

Our argument is that reflexive mitigation is an ecologically effective – and therefore strategic – response to climate change. We use the term reflexive in two ways. First, in the Beckian (Beck 1992, 1995) sense: climate change is a creation of our own making, rather than a risk originating in the natural world. Further, climate change risk is large-scale and challenging spatially (i.e. global) and temporally (i.e. multi-generational in the making, requiring at a minimum many decades to mitigate, with varying aspects of the phenomenon manifesting at varied timescales, and with some committed impacts effectively permanent (Solomon *et al.* 2009). Climate change is a characterising feature of Beck's late-modern civilization. The obvious corollary to this analysis is that halting and reversing anthropogenic climate change centres on changes in human-social systems.

Second, using the term reflexive emphasises that we advocate adaptive policy-making (TERI and IISD 2006) in relation to mitigation. Such an approach recognises that the Earth system, the global economy and the insurance system are connected social-ecological systems at varying scales. Accordingly: (i) maximum atmospheric CO_2e concentrations consistent with achieving and maintaining Earth system stability will vary over time in response to changes in the Earth system, the global economy, and the relationship between them; and (ii) relationships between the Earth system and smaller component systems including the global economy and the insurance system are evolving and therefore understanding of them is necessarily, and permanently, incomplete.

Ecologically effective mitigation refers to mitigation that delivers cuts in anthropogenic emissions sufficiently rapidly and deeply to avoid dangerous climate change. Industrialisation has produced a rise in atmospheric CO_2e concentrations from pre-industrial levels of 280 ppm to current levels of 385 ppm – and concentration levels continue to rise. In contrast, a drop in concentrations to at least 350 ppm – and perhaps lower – is required (Hansen *et al.* 2008). A reflexive approach to mitigation aims for specific atmospheric concentration levels whilst acknowledging that scientific understanding of what levels are necessary will likely continue to change.

Figure 2 presents a reflexive mitigation scenario for the insurance system. The initial conservation phase describes the current state of the insurance system: the system has accumulated substantial financial and intellectual capital, is founded on a linear understanding of the Earth system, and is viable on the basis of the Earth remaining in a familiar and relatively stable state, where past experience provides a reasonable guide to future experience. The insurance system is therefore vulnerable to anthropogenic greenhouse gas emissions pushing the Earth system out of its current familiar and stable state.

Potential release phase events are combinations of sudden shocks and accumulated stresses, originating in climate changes in the larger Earth system, that increase the insurance system vulnerabilities indirectly through impacts to the global economy as well as directly. Shock events include weather catastrophes such as floods and heatwaves (Allen *et al.* 2007). Stress events include climate impacts such as multi-year droughts, effectively permanent shifts in rainfall patterns, and sea-level rise (Solomon *et al.* 2009). Climate change impacts can cascade though the global economy, impacting the insurance system in multiple ways. Over time uncertainty increases and predictability and insurability decrease. Insurance system stability decreases, as does societal faith in the insurance system.

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Figure 2 about here

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At the reorganisation phase, a new sustainable foundation for the insurance system is created, grounded in acceptance of system non-linearity, system interdependence, and in particular, the dependence of the insurance system and the global economy on the Earth system. This implies substantial change to insurance system structure and practice. The insurance system disengages from climate change risk-creating activity (e.g. insuring and investing in the fossil fuel sector). This action alone supports reflexive mitigation policy and action in other social-ecological subsystems that are components of the overall economy. Instead, the insurance system is reoriented around strongly mitigative and adaptive approaches to climate change.

At the exploitation phase, characterised by rapid growth, the insurance system is fully geared to mitigate climate change through supporting cuts in emissions and protecting surviving carbon sinks. The global economy is rapidly decarbonised. Such a shift is not wholly due to changes in the insurance system, however the larger change process in the global economy creates new risk management and opportunities for the insurance system. This is a significant shift for the insurance system and for the economy overall, and is achieved through many failures and some successes. Managing financial risk remains an important function in the economy.

This path leads to a genuinely new conservation phase, characterised by accumulation of financial and intellectual capital, where the insurance system is reconstituted on the basis of a non-linear understanding of the Earth system and recognition of system interdependence, and remains viable on the basis of the Earth system remaining in a familiar and stable state. A decarbonised global economy implies significant socioeconomic change, include the nature of risks covered and the manner in which they are covered by the insurance system.

Did a reflexive mitigation path for insurance appear post-Katrina?

Unprecedented events in the production and certification of catastrophe modelling in Florida in the aftermath of Hurricane Katrina can perhaps be described as an abortive transition by the insurance system to a reflexive approach to insurance in a climate-changed world. The Florida Commission on Hurricane Loss Projection Methodology (FCHLPM) was created in 1995 to evaluate computer models and other recently developed or improved actuarial methodologies for projecting hurricane losses, to ensure reliable projections of hurricane losses so that rates for residential property insurance are neither excessive nor inadequate (FCHLPM 2009). Catastrophe loss modellers submit their loss models to the FCHLPM annually for accreditation. Once accredited, loss modellers can provide their models to insurers as a basis for pricing hurricane risk.

In April 2007 the FCHLPM refused to accept Risk Management Solutions (RMS) RMS's US Hurricane Model (version six) because it gave more weight to higher levels of hurricane activity in recent years rather than simply averaging hurricane activity over the longer term (RMS 2007). The standard approach since the first generation of hurricane catastrophe loss models has been to base hurricane activity rates on the “average of history” (Muir-Wood and Grossi 2008, p. 310). In the US this generally means the period since 1900. However, in the period since 1995, and in comparison to the period 1970-1994, hurricane activity in the Atlantic basin has increased by 60%, with an increase in intense category 3-5 storms of 120%. In 2004 and 2005, storms including Katrina also made landfall in the US. “Acknowledging that the long-term historical baseline is no longer the best measure of current hurricane activity means it is necessary to be explicit about the intended time horizon of the catastrophe model” (Muir-Wood and Grossi 2008, p. 311). From a CAS perspective, the more important point is it also means acknowledging non-linearity in the Earth system.

After refusal, a modified model incorporating the standard long-term historical baseline was submitted, which the FCHLPM subsequently accepted. The impasse was resolved simply by RMS complying with the provisions of the law. Nevertheless RMS continues to assert that the medium-term basis for projecting hurricane activity is better than the traditional long-term basis (RMS 2007). This highlights questions of sustainability of the insurance system in the longer-term. Muir-Wood and colleagues (2006) suggest that after accounting for changes in population and wealth, changes in extreme weather events may be responsible for a growth in insured losses by about two percent a year since the 1970s, and that this corresponds with rising global temperatures (Muir-Wood *et al.* 2006; Ward *et al.* 2008).

A stable basis for adaptation with grace

We argue that mitigation and adaptation approaches are linked: effective mitigation is a precondition for effective adaptation. We consider <u>adaptation with grace</u> as effective adaptation undertaken in an orderly and planned manner, embodying important principles of justice and equity, and with some hope of longevity. Adaptation with grace is wholly dependent on relative system stability provided by reflexive mitigation.

Adaptation to anthropogenic climate change in support of human welfare is necessary, given manifest climate change impacts and existing warming commitment in the Earth system (Hansen *et al.* 2008). Limits to climate change impacts – and therefore a basis for effective adaptation over the longer-term – relies on urgent mitigation action so that the Earth system remains in its current familiar and stable state. In the absence of familiar Earth system stability, potential adaptation efforts will be limited to <u>ad hoc</u> and reactive measures with reduced prospects for reflecting widely-shared ideas of fairness and equity, and with the term of benefits constrained by further changes in the Earth system.

Adaptation to climate change: Business-as-usual

Attempting to survive changed circumstances under varied, even extreme conditions is standard practice for human beings, human institutions, and for living organisms generally. For this reason we suggest the insurance system's generally adaptive and weakly mitigative responses to climate change (Phelan *et al.* forthcoming) may be reasonably described business-as-usual (BAU). Adaptation measures may be characterised as proactive or reactive and may be successful or unsuccessful in result. Whatever the character or outcome of an adaptive response, adaptation is always a reaction to context as opposed to a conscious shaping of context. In this section we reprise the four-phase adaptive cycle used in the previous section to contrast the insurance system's current response to climate change. The key limitation of adaptive and weakly mitigative approaches to climate change is their basis in a linear rather than non-linear understanding of the Earth system: this is the source of risk in the approach.

In conceptualising the insurance system pursuing an adaptive, BAU path, the initial conservation and release phases representing the current state of the insurance system and the impact on the system of climate risks are common to both the adaptation scenario and the mitigation scenario explored previously.

Paths diverge at the reorganisation phase: in the BAU scenario, the extent of reorganisation is minimal and the linear understanding of insurance remains. The insurance system adapts by making internal changes to compensate for climate change impacts to the global economy and to the insurance system itself. The system overall and elements within it are rebuilt and consolidated around reset linear understandings of the Earth system and cross-scale interactions. Examples include recalculation of maximum probable losses, increases to deductibles and limits to cover, industry withdrawal of cover from high-risk areas in extreme cases, and governments establishing state-backed insurance schemes to compensate for industry withdrawal. The insurance availability crisis is understood and responded to as a market failure and is not recognised as a system failure and instead: from this perspective, industry consolidation and government bailouts appear to be sound solutions. The insurance system have travelled this path previously, in relation to climate change and other risks. Examples include: insurers withdrawing cover for hurricane damage in Florida; and governments instituting state-backed insurance coverage in the face of industry withdrawal (Mills *et al.* 2005).

At the exploitation phase adaptive responses include efforts to increase capacity for accommodating risk internally to the insurance system and efforts to shift risk up scales beyond the insurance system. Examples include recalculating estimates of maximum probable losses on a linear basis, risk swaps to spread uncorrelated risks such as hurricanes in the Caribbean and earthquakes in Japan (Cummins 2007), and insurers creating insurance-linked securities is one example noted above. Shifting financial risk up a scale from the insurance system to the global economy without effectively dealing with the source of climate risk comes at a price: larger-scale risk and therefore higher stakes. The 2008 Global Financial Crisis is an example of larger-scale risk impacting the global economy as a whole and with specific implications for insurers by virtue of inter-system linkages. Whilst successful adaptive measures can increase system capacity to manage financial risk in the short term, they mask the cost of larger-scale failure later.

At the second iteration of the conservation phase, the 'new' state of the insurance system resembles the previous state. The risks to insurance system viability are greater. Over time the cycle of system collapse and rebuilding is repeated, perhaps at accelerating frequency, and certainly at greater magnitude. Overall the potential for a viable insurance system is much more constrained: repeated shocks and accumulated stresses take their toll on the overall system. Ultimately, insurance system resilience is undermined to the extent the system flips into an alternate state. Even as the current state of the system no longer remains, it may be that insurance in some form remains viable. For example, insurance for risks could remain viable at significantly reduced geographic and temporal scales. Insurance for total losses may be replaced by partial loss insurance. Thus BAU insurance system responses constitute a high-risk approach to climate change, one in which the longer-term viability of the insurance system overall is unclear.

Conclusion

We suggest the future viability of the insurance system in its current state is dependent on decarbonising the global economy. A CAS analysis demonstrates this by highlighting the non-linearity of the Earth system as a complex adaptive system, and linkages between the Earth system, the global economy, and the insurance system. In contrast, the insurance system currently operates on the basis of an incompatible linear understanding of the Earth system. In this context apparent adaptive responses of the insurance system to climate change may prove to be maladaptive responses. Adaptation is not an ecologically effective response to climate change for social-ecological systems nested within the economy, including the insurance system.

The implications of this conclusion are profound. Insurance formalises risk pooling and shifting. Given contemporary societal reliance on insurance, large sections of the global economy would be radically reshaped were the insurance system substantially transformed, or were access to insurance to become more difficult. Depending on the extent and pace of the transformation of the insurance system, this might imply rapid socio-economic change on an unprecedented scale.

Despite insurance's long history (Trennery 1926; Pfeffer and Klock 1974), large populations globally continue to survive with minimal engagement with the formal insurance system such as the welfare state and insurance markets. As we've argued, attempted adaptation is possible under all sorts of conditions. Risk sharing is also arranged informally, for example within families and communities. Societies can exist without insurance systems: even the end of insurance as we know it does not mean the end of human societies.

The insurance system may still function if pushed into an alternate state, though perhaps in a way that is currently unrecognisable. For example, insurance coverage may be available but in a substantially reduced form. This includes reductions in the spatial and temporal scales at which insurance operates, the type and magnitude of risks that are insurable, and the degree of compensation available for losses.

Decarbonising the global economy is an extraordinary challenge but one that the insurance system can address proactively. Commitments to carbon use in human-social systems are infrastructural, financial, political economic and socio-cultural. The insurance system is as ensnared by such commitments as other sectors in the global economy. In contrast, the existing warming commitment in the Earth system implies processes and impacts that cannot be wound back: commitments to warming already present in the Earth system are non-negotiable. Forcing the ecologically necessary shift in the global economy is an enormous challenge, but an attractive one to the extent that it offers an upper limit to climate impacts.

The challenge of decarbonising the global economy calls for thinking at large scale, spatially and temporally. The insurance system alone cannot achieve this; equally, decarbonising the global economy will not be achieved without a full contribution from the insurance system. Our argument is that reflexive mitigation is an ecologically effective – and therefore strategic

– response to climate change. Reflexive mitigation is proposed here as an insurance system response to climate change. It may be that reflexive mitigation strategies are appropriate for other social-ecological subsystems of the global economy also. Successful reflexive mitigation of climate change holds out real prospects for effective adaptation to climate change, adaptation with grace.

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Figures & captions

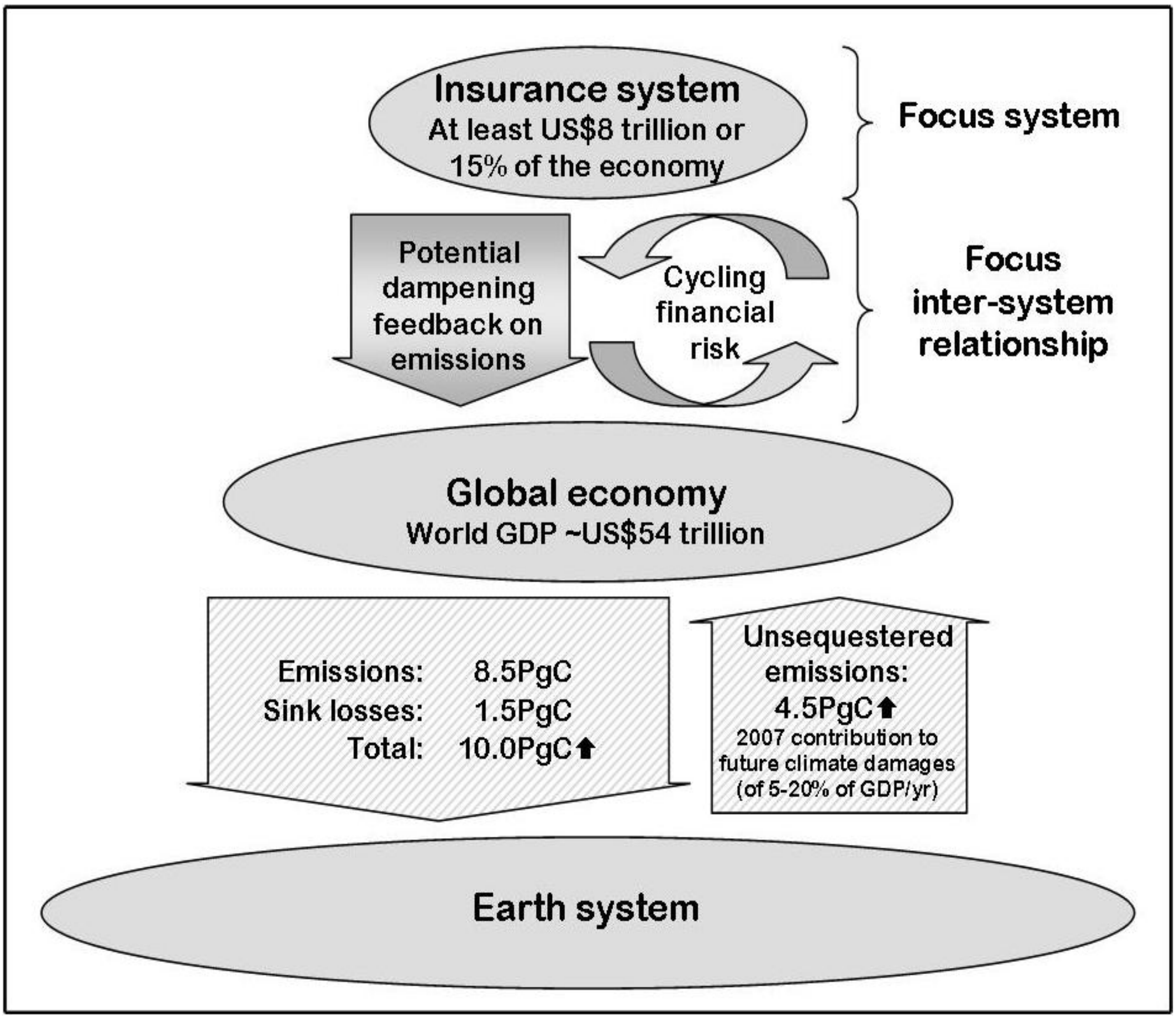

Figure 1: The insurance system, the global economy and the Earth system, and key interactions among them: a 'snapshot' from 2007.

The insurance system is depicted as nested within the global economy, and in turn within the Earth system. Financial risk cycling (semi-circular arrows) by the insurance system pools and spreads climate (and other financial) risks across the global economy. Reflexive mitigation action by the insurance system may create beneficial dampening (or negative) feedback effects between the insurance system and the global economy (downward arrow from the insurance system to the global economy), and so encourage or even drive reduction in anthropogenic emissions from the global economy. The value of insurance system activity in 2007 is at least US$8 trillion* or 15% of the global economy, valued that year at ~US$54 trillion.

The Earth system incorporates the physical and chemical environment, the biosphere and also all human activities. The Earth system is without substitute and for the purposes of our analysis the Earth system remains unvalued in financial terms. Current anthropogenic CO_2e emissions and future climate damages are the key interactions between the global economy and the Earth system (this figure represents CO_2 only, the major greenhouse gas). In 2007 the atmospheric 'insult' from the global economy comprises CO_2 emissions totalling ~8.5 PgC* and destruction of CO_2 sinks of ~1.5 PgC totalling an additional 10 PgC. Global greenhouse gas emission rates continue to rise, indicated by the '⬆'. In 2007 around 45% of CO_2 emissions remained in the atmosphere, destined to return to the global economy as increased climate-related damages. The proportion of CO_2 emissions that remain unsequestered by the Earth system is also increasing over time, also indicated by an '⬆'. Stern (2006) estimates future climate damages in the order of 5-20% of global GDP each year in the absence of strong mitigation.

** 1 trillion = 1000 billion*

*** 1 Pg (petagram) = 1 billion (or 1000 million) tonnes.*

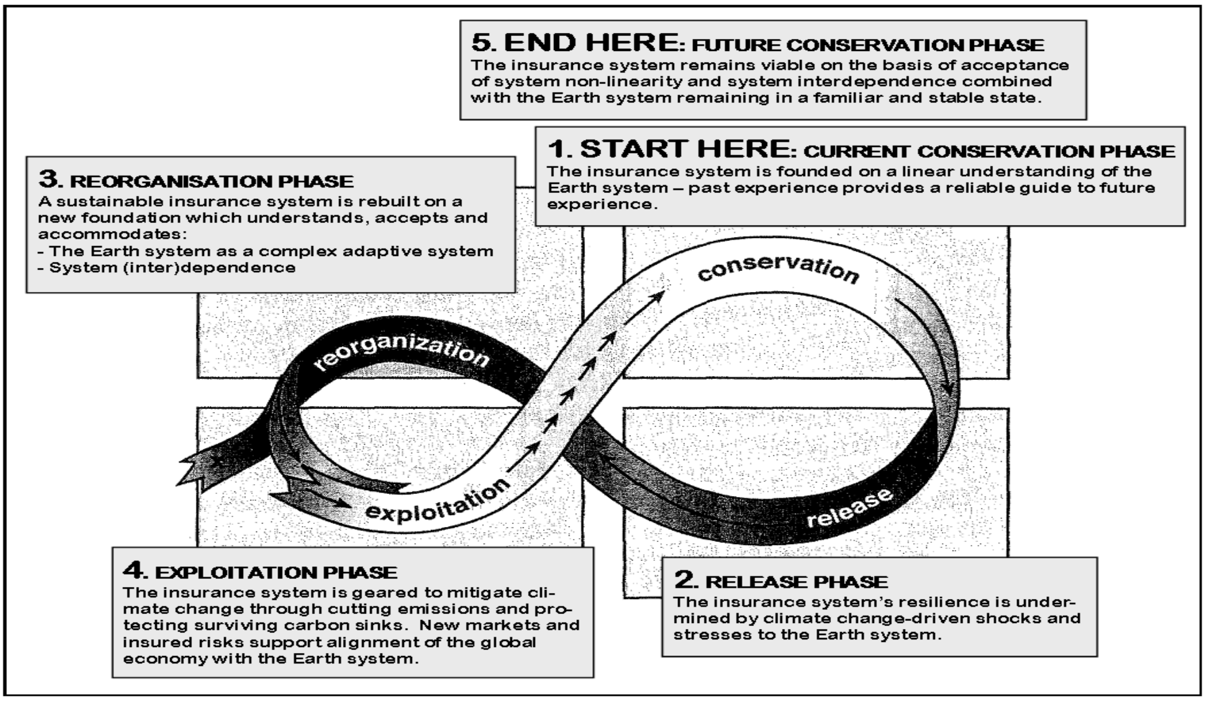

Figure 2: An alternative path for the insurance system: reflexive mitigation and insurance system sustainability. Source: Adapted from (Holling and Gunderson, 2002), p.34

The four-phase adaptive cycle is an heuristic developed to explain change processes in social-ecological systems. It is applied here to demonstrate the insurance system's potential transition from a linear to a non-linear operational basis. The cycle begins (at '1') with a description of the insurance system in it current form, characterised by a linear understanding of the Earth system. In the current *conservation* phase, past experience remains a reliable guide to future experience, giving meaning to terms such as '1 in a 100 year flood'. The *release* phase (at '2') sees the insurance system's resilience undermined by unanticipated climate change-driven shocks and stresses, a result of climate change having pushed the Earth system from a state of relative predictability to relative unpredictability. The implications of climate change on the insurance system are acknowledged and the *reorganisation* phase (at '3') sees the insurance system rebuilt on an new foundation which recognises (i) the Earth system is a complex adaptive system, and (ii) interdependence of systems, and in particular, the dependence of the insurance system and the global economy on the Earth system remaining in a stable and familiar state. The *exploitation* phase (at '4') sees the insurance system geared to climate change mitigation through rapid and deep cuts in greenhouse gas emissions and protecting surviving carbon sinks. New governance arrangements see the insurance system used to encourage the alignment of the global economy with Earth system limits. Climate change is effectively mitigated and the insurance system enters a new *conservation* phase (at ‘5’), remaining viable on the basis of the Earth system remaining in a stable and familiar state.

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6. An insurance basis for carbon prices

6.1 Introduction

This chapter, based on the paper D ‘Climate change, carbon prices and insurance systems’, proposes an insurance basis for carbon pricing, consistent with the objective of bringing the carbon-based economy into alignment with the limits of the Earth system. Mitigating anthropogenic climate change requires (i) deep and rapid cuts in greenhouse gas emissions, and (ii) the conservation and expansion of surviving carbon sinks.

Market approaches to limit carbon dioxide equivalent (CO_2e) emissions such as carbon taxes and emissions trading schemes aim to avoid dangerous anthropogenic climate change by ascribing a financial cost to emissions. Such approaches have failed to establish either emissions limits or carbon prices equal to the task. This chapter argues that current approaches fail in part because they are not designed to deliver ecologically adequate cuts in emissions.

The approach to carbon pricing proposed in this chapter draws on aspects of insurance systems to better reflect the Earth system’s biogeophysical limits. The proposal provides a role for the insurance system geared explicitly to mitigation of anthropogenic climate change. This contrasts with previous proposals for insurance system engagement with anthropogenic climate change which are limited to adaptive and weakly mitigative roles such as those described in Chapter Four. The new concept described here provides both a scientific–technical capacity and a political–economic incentive to shift the anchor point for carbon prices away from pressing short-term political and economic considerations and closer to strategic ecological requirements for Earth system stability. The proposal, a departure from current approaches to pricing CO_2e emissions, requires participation by states and a small number of larger and established reinsurers.

This chapter contributes to the overall thesis by demonstrating a theoretically feasible application of insurance systems to strong mitigation of anthropogenic climate change. The application is grounded in the reflexive mitigation approach introduced in Chapter Five.

6.2 Contribution of paper D in the context of the overall thesis

Table 6.1: Contribution of paper D in the context of the overall thesis

Thick borders identify the research questions to which paper D responds.

1	**Research aim: what does anthropogenic climate change mean for the insurance system?**	
1.a	Research question: If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, *i.e.* is the threat temporary, intermittent, permanent, strategic, or existential?	
	Response: • *Permanent, strategic and possibly existential.*	*Locations:* • *Chapter 3/paper A; Chapter 4/paper B; and Chapter 5/paper C*
1.b	Research question: To what extent might anthropogenic climate change present an opportunity to the insurance system?	
	Responses: • *Limited and short-term if at all in the absence of effective mitigation. Ultimately anthropogenic climate change threatens the viability of the insurance system as currently structured.* • *In contrast anthropogenic climate change mitigation presents a theoretical opportunity to the insurance system.*	*Locations:* • *Chapter 4/paper B; Chapter 5/paper C; and* • *Chapter 6/paper D.*
2	**Research aim: how might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?**	
2.a	Research question: How has the insurance system approached anthropogenic climate change to date?	
	Response: • *Strongest insurance system responses to anthropogenic climate change to date are generally adaptive and weakly mitigative.*	*Location:* • *Chapter 4/paper B*
2.b	Research question: If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?	
	Response: • *Yes: theoretically such potential exists.*	*Locations:* • *Chapter 5/paper C; and Chapter 6/paper D.*
3	**Research aim: how might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?**	
3.a	Research question: What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?	
	Response location: • *Chapter 7/paper E.*	
3.b	Research question: If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?	
	Response location: • *Chapter 7/paper E.*	

6.3 Paper D: 'Climate change, carbon prices and insurance systems'

Paper:

Phelan, L., Henderson-Sellers, A., & Taplin, R. 2010. Climate change, carbon prices and insurance systems. *International Journal of Sustainable Development and World Ecology*. 17(2): 95-108.

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Climate change, carbon prices and insurance systems

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Market approaches to limit CO_2e emissions such as carbon taxes and emissions trading schemes (ETSs) aim to avoid dangerous anthropogenic climate change by ascribing a financial cost to emissions. Yet such approaches have failed to establish either emissions limits or carbon prices equal to the task. We propose an approach to carbon pricing that better reflects the biogeophysical limits of the Earth system by drawing on aspects of insurance systems including forms of social insurance and the insurance industry. Our proposal achieves this by: (i) creating a financial liability link between current emissions and attributable near future losses; and (ii) applying Fraction Attributable Risk (FAR) analysis to determine the contribution of anthropogenic climate change to increased probability of experienced damaging weather events. Our proposal, a departure from current approaches to pricing CO_2e emissions, has aspects that are consistent with existing forms of insurance. It requires participation by states and a small number of larger and established reinsurers. Our proposal provides both the scientific–technical capacity and the political–economic incentive to shift the anchor point for carbon prices away from pressing short-term political and economic considerations and closer to strategic ecological requirements for Earth system stability: the balance is shifted to favour changes in the global economy necessary to avoid dangerous anthropogenic climate change over current estimations of what is politically and economically feasible or desirable. Our proposal is an example of reflexive mitigation, grounded in complex adaptive systems theory, and centres on relationships between the Earth system, the global economy and insurance systems.

Keywords: climate change; carbon price; insurance; reflexive mitigation; adaptation; complex adaptive systems

Carbon prices that reflect biogeophysical limits: a role for insurance systems

Market approaches to climate change mitigation are designed to drive CO_2e emissions[1] reductions in the global economy by ascribing a financial cost to emissions (Stern 2006: 449). Two common approaches that operationalise carbon pricing are carbon taxes and emissions trading schemes (ETSs) (Ekins and Barker 2001).[2] To date carbon emission prices have been unrealistically low. Andrew (2008: 339) notes for example that 'European governments have been guilty of allowing their industries as much CO_2 as they could emit at little or no cost.' This is perhaps not surprising: the *status quo* is a global economy dependent on limitless, uncosted fossil fuel emissions. Structurally powerful fossil fuel interests have been successful till now in organising effectively to defend their interests, in part by framing their interests as the interests of society in general (Paterson 2001).

Policy-makers implementing carbon pricing have failed to either aim for, or achieve, prices or limits to emissions that accurately reflect the biogeophysical limits of the Earth system. Despite decades of policy discussion, design and implementation, global CO_2e emissions rates and atmospheric concentrations continue to rise well beyond (rather than reduce to within) biogeophysical limits: '... the acceleration of both CO_2 emissions and atmospheric accumulation [in the period 2000–2007] are unprecedented and most astonishing during a decade of intense international developments to address climate change' (Global Carbon Project 2008b). Carbon prices in such schemes instead closely reflect pressing and legitimate but short-term political and economic considerations including decision-makers' current estimations of what is politically and economically feasible or desirable. The Australian Government's proposed ETS (Commonwealth of Australia 2008), and the preceding *Garnaut Review* (Garnaut 2008) that informed it, are examples. As such the ecological effectiveness and therefore the strategic value of such measures is unclear. We define 'ecologically effective' as reductions in emissions sufficient to avoid dangerous anthropogenic climate change.

In this paper we propose a means of generating carbon prices that draws on aspects of insurance systems to better reflect the biogeophysical limits of the Earth system. Our proposal's theoretical basis in complex adaptive systems theory is presented in section two. Key features and elements are presented in sections three and four. Section five introduces important ancillary opportunities that our proposal provides in the areas of indirect support to other mitigation policies and action, and inter- and intragenerational equity. The paper concludes with discussion of our proposal and future directions for research in section six.

The earth, the economy and insurance: systems in relationship

Our proposal for carbon pricing linked with insurance systems is grounded in an understanding of the Earth system, the global economy and insurance systems as connected complex adaptive systems (Phelan et al. forthcoming). In theoretical terms this means recognising cross-scale linkages between systems and making changes in one system

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(insurance systems) to effect changes in another larger system (the global economy) and so foster its alignment with a yet larger third system (the Earth system).

We use the term 'insurance systems' and not 'insurance industry' purposely to bring focus to all of the participants in insurance systems and their relationships that together allow ongoing provision and use of financially viable insurance. This explicitly includes welfare state-style social insurances such as universal health care, unemployment benefits and age and disability pensions. 'Insurance systems' also includes participants in what is more commonly understood to be the insurance industry such as for-profit and mutual insurers, government insurers, reinsurers, specialised service suppliers such as loss modellers and brokers, government regulatory authorities and industry representative bodies. Investors in insurance companies as well as insurers' substantial investments are also included. The term also includes the legal and institutional frameworks created and used to facilitate access to insurance. We use the term 'global economy' to refer to the source of anthropogenic greenhouse gas emissions. We use the term 'Earth system' to describe to the integrated socio-ecological system that is planet Earth and all life on it, including human societies. This theoretical approach is provided in more detail in Phelan et al. (forthcoming).

The scientific basis for anthropogenic climate change as a globally coherent phenomenon and the need for substantial cuts in CO_2e emissions are established (IPCC 2007a; Hansen et al. 2008). Our proposal proceeds on the uncontroversial assumption that climate change impacts will continue to grow with emissions and this will lead to substantial economic losses across the carbon economy. The threat climate change presents to human social systems is the motivation for climate change mitigation and adaptation, as articulated in the United Nations Framework Convention on Climate Change (United Nations 1992). The Intergovernmental Panel on Climate Change has repeatedly communicated the reality and implications of climate change (IPCC 2001, 2007a). The *Stern Review* (Stern 2006) and the *Garnaut Review* (Garnaut 2008) provide economic analyses of climate change impacts with regard to the global economy and the Australian economy respectively.

Reflexive mitigation: an adaptive approach

Reflexive mitigation (Phelan et al. forthcoming) describes an adaptive approach to mitigating climate change. Reflexive mitigation is an adaptive approach to mitigating climate change recognising: (i) maximum atmospheric CO_2e concentrations consistent with Earth system stability will vary over time in response to changes in the Earth system, the global economy (the source of anthropogenic CO_2e emissions), and the relationship between them; and (ii) relationships between the Earth system and smaller component systems including the global economy and insurance systems are evolving and therefore understanding of them is necessarily incomplete. Changes in complex adaptive systems such as the Earth system are typically non-linear and unpredictable. As such climate change policy development and action proceeds under conditions of uncertainty (TERI & IISD 2006). Accordingly, mitigation measures must be adaptive to allow for consistency with continual and sometimes rapid changes in the Earth system, and in scientific understanding of the Earth system. One example is potentially rapidly changing scientific estimates of what constitutes a stable atmospheric CO_2e burden and required reductions in CO_2e emissions. In contrast standard approaches to mitigating climate change are more rigid, for example adopting a limit of 2°C warming (Meinshausen et al. 2009), and so less capable of responding rapidly should this target be shown in time to be inconsistent with climate stability.

Defining and then undertaking specific action necessary to avoid dangerous anthropogenic climate change is complicated, difficult and uncertain (Garnaut 2008). Against the backdrop of 'unequivocal' climate system warming (IPCC 2007a), there is considerable uncertainty about significant Earth system thresholds (Lenton et al. 2008) and our scientific capacity to identify tipping points in the Earth system, sometimes even long after they have been passed (Keller et al. 2007, 2008). Uncertainty is an inherent feature of the Earth system. Uncertainty will increase as the climate continues to change in response to continuing (and increasing) CO_2e emissions and as decision-makers continue to struggle to respond adequately.

Scientific understanding of climate change is continuously evolving and public policy responses to climate change will be more effective when they become more responsive to new scientific research as it is generated. Current best estimates for targets for atmospheric CO_2e concentrations consistent with climate stability indicate the need for a drop from current levels of *circa* 385 to 350 ppm or lower (Hansen et al. 2008). In contrast, public policy responses struggle to reflect scientific analysis. Exchanges between scientists and political leaders at the March 2009 Copenhagen Climate Change Congress held in preparation for the COP-15 negotiations revealed both the dynamism of effective emissions reductions targets, and the challenge of dealing politically with such Earth system dynamism (see Kalaugher 2009). Influential economic analyses (e.g. Stern 2006; Garnaut 2008) serving as bases for policy responses to climate change have stalled on assumed targets for global atmospheric CO_2e concentrations in the range 450–550 ppm – well short of adequate.

It would be prudent to anticipate some variation in these estimates as climate change continues to be experienced and as scientific understanding continues to evolve. In practice observed rates of climate change are repeatedly underestimated. One example is projected rates of sea level rise. In 2007 the IPCC's (2007c) mid-range projection for sea level rise over the course of the current century was in the order of 0.5 m. In less than 2 years that estimate has doubled (McLeod 2009). Under all realistic scenarios, avoiding dangerous (however defined) anthropogenic climate change requires rapid and deep cuts in global CO_2e emissions.[3]

Proposal features

In this section we outline our proposal for carbon prices as having two key features that partially address the relationship between the Earth system and the dependent global economy: (i) creation of a financial liability link between current emissions and attributable near future (*circa* 20 years) losses; and (ii) acceptance and application of the Fractional Attributable Risk method of analysis to demonstrate causation for financial losses (Allen and Stainforth 2002; Stott et al. 2004; Stone and Allen 2005; Allen et al. 2007, and discussed below). In combination, these features constitute the core of a climate change policy response that gives form to the reflexive mitigation approach described above.

Liability: current emissions and attributable near future financial losses

A liability link between current CO_2e emissions and attributable near future financial losses begins to account for the relationship between the carbon economy and the Earth system on which it depends. Our proposal adopts future financial losses in the global economy caused by current emissions as a proxy for future environmental damage in the Earth system.

Responsibility for potential future financial losses caused by current emissions is then dealt with via insurance; that is, liability is allocated to existing reinsurance organisations with the consent and support of governments. This creates a major financial incentive for those organisations to ensure payments (a *quasi*-premium) received for current emissions are sufficient to maintaining solvency and provide for future claims. Creating and maintaining liability links over time requires dependable rule of law, which relies directly on governments and in turn on broader social system stability.

Fraction attributable risk

Establishing climate change liability links requires technical capacity to attribute a weather event or trend resulting in financial losses to anthropogenic CO_2e emissions. This may never be directly possible in a complex adaptive system such as the Earth: particular loss-causing extreme weather events may occur by chance in the absence of any anthropogenic climate change. Instead, Stone and Allen (2005) draw on epidemiological approaches to causation to focus on Fraction Attributable Risk (FAR), or 'the risk of [an] event occurring, rather than the occurrence of [an] event itself' (p. 304). The FAR concept was developed for population studies in epidemiology, and Allen et al. (2007) apply it in 'the analysis of an unprecedented change in a single system … the world's climate' (p. 1357). Allen et al. (2007) use the term FAR 'methodology' to refer to the discrete modelling process they describe. We use the term 'method' to limit meaning to the process described, and so avoid confusion with common social science understandings of the term 'methodology', which typically refer to broader understandings of scientific inquiry, complete with ontological and epistemological foundations and standard forms of practice.

Applying FAR method results in a probabilistic quantity: the probability of a specific event occurring. A proportion of the probability of an event's occurrence can be attributed to anthropogenic CO_2e emissions. This allows consideration of the extent to which 'human influence on climate can be "blamed" for observed weather trends and specific weather events such as floods, storms or heatwaves' (Stott et al. 2004).

The FAR method builds on earlier probabilistic approaches: Stone and Allen (2005) draw on Barsugli et al. (1999) and Palmer and Räisänen (2002). Its application (Stott et al. 2004) to the 2003 European heatwave that caused 35,000 premature deaths and in excess of €13.1billion (UK Met Office 2008) in lost agricultural production and fire damage is described as a 'breakthrough: it is the first successful attempt to detect man-made [sic] influence on a specific extreme climatic event' (Schär and Jendritzky 2004: 560). The initial application of FAR to the 2003 European heatwave combined with a conservative application of statistics concluded that very likely (i.e. greater than 90% chance) 'human influence … increased the risk of the 2003 heatwave by a factor of at least two, with the most likely increase … considerably greater than two.' (Allen et al. 2007: 1393).

A later study by Allen et al. (2007) on 'Scientific challenges in the attribution of harm to human influence on climate' applied a statistical approach described as more realistic and consistent with standard practice for modelling extreme value distributions. This study determined human influence increased in the risk of the event occurring by a factor of four to ten, with the most likely value being six (Allen et al. 2007: 1392–1393). Another way to say this is that 85% of the risk of the heatwave occurring was due to human interference with the climate (Allen et al. 2007: 1393).

This later study appears in a law journal and can be seen as an attempt by climate scientists to reach out to the legal community, seeking agreement 'on an "industry standard" operational approach to the attribution problem' (Allen et al. 2007: 1355). The authors argue that FAR analysis provides the capacity to determine the extent to which a recent past large scale, financially damaging weather event was more likely to have occurred because of human interference with the climate. Others have since extended the approach by linking the FAR method with sophisticated statistical techniques to render the FAR method applicable to smaller-scale events (Jaeger et al. 2008).

There are a number of constraints to applying the FAR method associated with the contexts in which the method can be applied with confidence. The starting point for the FAR method is the current state of the atmosphere, i.e. complete with the existing anthropogenic atmospheric CO_2e burden. The key question then becomes: 'how not injecting that [already emitted] amount of carbon dioxide would alter our present-day and projected future climate' (Allen et al. 2007: 1359). Note that FAR method does not make use of information from earlier historical and prehistoric atmospheric states. As such the FAR method avoids reliance on scientific understanding of past states of the climate for which there is less reliable data. Allen et al. (2007) note that the reference conditions used by the scientific community are defined as 'the climate that would have occurred in the early twenty-first century in the absence of specific human influences' (p. 1366). In fact the climate has been subject to 'specific human influences,' and so those conditions can only be explored using computer simulation. The FAR method adopts the computer-simulated baseline as the 'natural' or reference climate.

Turning to quantifying human influence on climate, Allen et al. (2007: 1374), ask the legal community to reach agreement on what 'constitutes an adequate explanation of recent climate trends' for their purposes, adding that

> Within the scientific community, an explanation that is both physically coherent and consistent with the available data – meaning the data provide no indication that anything is missing from either forcings or response – is generally considered adequate (Allen et al. 2007: 1374).

On this basis Allen et al. (2007) note that 'most of the global warming over the past 50 years is very likely to have been due to the observed (anthropogenic) increase in GHG [greenhouse gas] levels' (p. 1375), and refer readers to the IPCC's 2007 *Fourth Assessment Report* (IPCC 2007b). In highlighting the temporal scale constraints to confidence about causes of warming, Allen et al. (2007: 1375–1376) are at pains to point out that scientific certainty about the anthropogenic cause of climate change is strongest for the past 50 years, and that 'knowledge about recent climate change is most relevant to quantifying the impact of CO_2e emissions to date and to predicting future climate change' (Allen et al. 2007: 1376). Thus Allen et al. (2007: 1378–1383) use a property of the climate system, 'Transient Climate Response'[4] which also attracts substantial scientific consensus and which can be employed over such a time scale as short as the past 50 years and the next two decades or so.

Allen et al. limit their perspective to present day and near future losses, where near future means 'within the next decade or two' (2007: 1383). They note that the climate responds to current atmospheric CO_2e concentrations, not changes in levels of emissions: as such changes in emissions levels 'will take at least a couple of decades to have a significant impact on the climate' (2007: 1383). Given this lag in the climate system, the climate of the next quarter century will be the result of human decisions that have already been made, combined with natural factors, some of which may be in the future, for example volcanic eruptions. Allen et al. (2007: 1383) also acknowledge a corollary of that system lag: decisions made now and in the immediate future are likely to have little impact on the climate before 2025.

Allen et al. (2007: 1385) present 'probabilistic event attribution' as a quantitative approach to causal attribution (Stone and Allen 2005). This approach focuses on 'attributing changes in the risk of an event occurring to external drivers of climate rather than attempting to dissect the event itself' (Allen et al. 2007: 1385), and requires adoption of a probabilistic framework. The likelihood of an extreme weather event occurring can be proportionally allocated to multiple causes. In contrast, neither the event itself, nor its impacts (e.g. total rain in a freak storm and ensuing damage), can be proportionally allocated to multiple causes.

The FAR method requires careful definition of the event for which probabilistic attribution is being calculated and this is addressed in detail in Allen et al. (2007). Recalling that the reference climate used in the scientific community is 'the climate that would have occurred in the early twenty-first century in the absence of specific human influences,' the next question is how that risk might change if anthropogenic CO_2e emissions had not occurred. In short, the question the FAR method can answer is: How much more likely was a specific extreme weather event because of anthropogenic climate change?

Allen et al. (2007: 1394–1395) conclude their paper with a series of issues that require consideration if the FAR method is to be adopted by the legal community, centred on the parameters in which the method could be operationalised.

Adoption of the FAR method by insurance systems towards generating carbon prices similarly would require translating the method from the climate sciences across to the loss modelling and actuarial disciplines. We suggest that in comparison to legal systems' adoption of the method, this may be easier for insurance systems because of their existing focus on risk modelling and management.

A reflexive approach to climate change mitigation drawing on the FAR method would integrate continuous application of the method to extreme weather events and trends, towards continuously evolving understanding of climate and associated financial losses. Applying the FAR method produces probabilistic results, that is the contribution of climate change to the increased likelihood of a defined event occurring (Allen et al. 2007). This information would in turn inform carbon prices.[5]

Limits in the Earth system and insurance systems

The Earth system has biogeophysical limits, and is characterised by thresholds and tipping points (Steffen et al. 2003). Globally significant Earth system thresholds threatened by anthropogenic climate change include melting Arctic sea-ice, the Greenland and West Antarctic Ice Sheets and the Atlantic thermohaline circulation (Lenton et al. 2008). Some changes can occur apparently suddenly or more rapidly than anticipated (Schneider 2003; Schellnhuber et al. 2006). Some changes are likely to be irreversible over a period of at least 1000 years and so from a human perspective, are in effect permanent (Solomon et al. 2009).

Insurance systems too have limits: some risks are 'beyond the insurance limit' (Beck 1992: 88). Risks are uninsurable for example where potential financial losses are too great and where uncertainty of loss probabilities is too high. This proposal arguably lies within insurance systems' limits. Insurance systems' use of the FAR method is designed to enforce limits on anthropogenic emissions consistent with Earth system limits. An approach to carbon prices that draws on aspects of insurance systems allows anticipated and attributable near future losses to be reflected in prices for current emissions. Anticipating increased likelihood or magnitude of attributable near future losses would provide a rationale for increasing current carbon prices. Conversely, anticipating decreased likelihood or magnitude of attributable near future losses would provide a rationale for reduced carbon prices.

Increasing uncertainty regarding probabilities (both frequency and magnitude) of future financial losses would also provide a rationale for increases in carbon prices. Conversely, decreased uncertainty regarding probabilities of future losses would allow decreases in carbon prices. As anthropogenic climate change continues to push the Earth system outside of a familiar stable state, Earth system unpredictability will increase. Therefore in the near term, if emissions continue to increase, carbon prices would be expected to increase.

Insurance systems can manage increased uncertainty to a point, for example by increasing premiums for insured assets (or in this case, by increasing carbon prices). However where uncertainty becomes too great, risks and therefore premiums move from less expensive to more expensive, and beyond to unpricable. Thus a carbon price generated, though insurance techniques would reflect (or feed back) to the economy, an indication of the capacity of the Earth system to bear additional CO_2e emissions and atmospheric concentrations, including biogeophysical limits. As such Earth system limits are not represented directly; anticipated financial losses in the global economy serve as a proxy for damages manifest in the Earth system. Ultimately, inability to price the risk associated with emissions represents climate risks increasing beyond the insurance limit.

The feedback provided by a carbon price that reflects Earth system limits may produce counterintuitive outcomes. Orthodox economic theory suggests that the more scarce a resource is compared to demand for the resource, the higher its price (*The Economist* 2009). Yet, for this carbon pricing scenario, the more available the resource (i.e. permission to emit), the higher the potential liabilities and, therefore, the higher the price of the resource. Higher current CO_2e emissions leads to higher atmospheric CO_2e concentrations and higher future risk, which would in turn lead to higher carbon prices currently. Conversely, lower current CO_2e emissions leads to lower atmospheric CO_2e concentrations and lower future risk, which would in turn lead to lower carbon prices. Thus, in this approach to carbon pricing the assumed relationship between scarcity and price is reversed. Systems theory labels this a negative feedback: a feedback that acts to dampen rather than reinforce a perturbation.

Continuous application of the FAR method provides a reference point for carbon prices that continuously refers to evolving scientific assessment of Earth system limits. Liability links current emissions and attributable estimated near future damages. In combination, this proposal provides the scientific–technical capacity and the political–economic incentive to shift the anchor point for carbon price away from immediate political economic considerations and towards strategic ecological requirements for Earth system stability. The balance is shifted to emphasise changes in the global economy necessary to avoid dangerous anthropogenic climate change over current estimations of what are politically and economically feasible or desirable.

Roles for states and reinsurers

Our proposal is a departure from current approaches to pricing CO_2e emissions. Our proposal invites, and requires, participation of states and a small number of larger, more established reinsurers and loss modellers. In particular, our proposal requires a high degree of coordination between states and globally significant reinsurers. Climate change is an unprecedented challenge for human civilisation and successful mitigation requires effective government leadership. States alone have the capacity in times of rapid change to simultaneously (i) appropriately distribute powers between itself and other actors, (ii) maintain legitimacy domestically, and (iii) maintain legitimacy externally (Hirst 2000: 31). Effective climate change mitigation requires fundamental change throughout socio-economic systems and cannot be implemented without broad engagement across societies (Phelan et al. forthcoming). Heavy regulation of insurance systems by governments is required if insurance systems are to play a role in climate change mitigation. For example, this proposal addresses climate-attributed losses and not any other variable that may exacerbate or ameliorate losses such as changes to building codes.

States appropriately distributing powers between themselves and other actors invite engagement by others involved in insurance. Other participants in insurance systems such as larger reinsurers and loss modellers also need to engage in strong mitigation action. Since the early 1990s, insurers and reinsurers have disappointed environmental civil society organisations and others advocating climate action by not matching expectations of their leadership potential in mitigating climate change (Paterson 2001). However reinsurers have substantial capacity to conduct or commission risk research, modelling and management and therefore have the potential to contribute constructively in this regard (Mills 2005).

This proposal provides a powerful political–economic incentive for reinsurers and loss modellers to engage in strong climate change mitigation action. Treating carbon prices as *quasi*-premiums, to be collected by larger reinsurers licensed by states to do so, means the creation of a very large new market and therefore a significant opportunity for making profit. Global emissions from fossil fuels and cement in 2007 alone totalled 8.5 billion tons (Global Carbon Project 2008a). Even applying an unrealistically low current carbon prices such as US$26[6] a ton suggests a new market valued in the order of US$221 billion. We suggest that emissions prices that better reflect the Earth's biogeophysical limits as reflected in anticipated financial losses would be higher, and therefore insurers' potential gross revenues would be higher. By creating such a substantial financial stake in future climatic stability, our proposal creates a powerful and immediate political economic motivation for insurers and states to pursue climatic stability.

Long-tail risks

Our proposal creates a new and substantial opportunity for reinsurers to generate profit. Even so, reinsurers may remain wary of our proposal because of the challenges of profitably pricing and managing risk over large temporal scales (Parsons 2003). Climate change liabilities (as with other environmental, product, and workplace liabilities such as contaminated sites, pharmaceuticals with side effects and asbestos exposure) can be considered long-tail liabilities, where 'an injury or other harm takes time to become known and a claim may be separated from the circumstances that caused it by as many as 25 years or more' (Rubin 2008: 296). Long-tail risks are difficult to manage (Munich Re 2008; International Chamber of Commerce 2008). New dimensions to liabilities can emerge over such extended periods and legal contexts can also change (Six 2005). In particular, retrospective application of liability increases uncertainty for insurers (Faure and Fenn 1999). The regulatory context in which the industry operates can also change over time (O'Hara 2006; Schiro 2006; Serio 2006). More broadly, changes in social norms over time pose serious challenges to assessing real liabilities: sources of risk may be contextual rather than inherent in the activity being insured (personal communication George Walker, Senior Risk Analyst, Aon Benfield Asia Pacific, 5 May 2009). Both climate change impacts and mitigation responses imply substantial social change. Changes in social norms around the climate implications of past actions could therefore also be expected to change.

Our proposal overall calls for a substantial degree of co-ordination between governments and reinsurers. Challenges associated with long-tail liabilities are a key area that requires attention. Governments may be able to ameliorate some uncertainty inherent in long-tail climate risk associated with our proposal. Faure and Fenn (1999: 498) offer two mechanisms for dealing with long-tail risks generally: (i) legislating for compulsory compensation funds in relation to the long-tail risk; and (ii) the use by courts of 'prospective overruling' to liability, whereby 'courts announce that they will adopt the previous standard of car in a particular case but announce that from now on they will adopt a different standard in future as a consequence of new information' (1999: 498). Elsewhere Faure deploys an economic analysis to caution that making insurance compulsory as a response to market failure 'may create more problems than it cures' (2006: 149). In the eventuality that reinsurers are unwilling to participate in implementation of the proposal, states could assume some or all of the reinsurance role.

Standards of insurability, moral hazard and existing insurance practice

In this section we consider our proposal with reference to the standards of insurability and comment on our proposal in relation to moral hazard. We also draw out consistencies between our proposal and aspects of existing insurance systems.

Standards of insurability

The 'time-tested' (Mills et al. 2001: 58) standards of insurability are a core consideration for commercial insurance practice (Hausmann 1998: 7; Kunreuther 1998). In theory, insurable risks are only those that meet the standards of insurability. Yet Denenberg et al. (1964: 146) describes the standards of insurability as key, but not cast in iron, arguing that in practice, 'it is fair to say that there is no peril currently being insured that meets fully and completely every requirement,' and that '[T]he elements of an insurable peril [are helpfully understood as] types of problems that must be considered in determining the insurability of a particular peril.' Whilst '[a] peril may fail to meet one or more ... requirements ... objections of this kind may be overcome ... through practical controls such as underwriting, policy provisions and [pricing] techniques.' In seeking to articulate how our proposal for a carbon price drawing on aspects of insurance systems would function we discuss the standards of insurability as provided by Mills et al. (2001: 58; with reference to Denenberg et al. 1964: 145–148), as a framework. Our proposal, which draws on aspects of both commercial and social insurance systems, displays some consistency with the first three standards of insurability. The relationship between our proposal and the latter two standards is more complex.

(1) There should be a large number of homogeneous exposures to permit the operation of the theory of probability and setting of actuarial rates.

Climate change is anticipated to produce large and increasing numbers of exposures. Exposures are highly variable. Therefore, the insurance basis for our proposal is only partially consistent with this standard. Our proposal is for a compensation scheme, however, similar to national disaster insurance in that it is designed to provide coverage to whole populations and is not expected to provide total restoration for individual losses. Thus there may be opportunity to artificially homogenise exposures through constrained definitions of exposures.

(2) The occurrence should be fortuitous; i.e. the timing or the severity of the loss should be out of the control of the insured.

The timing and severity of climate change-implicated losses is out of the control of the insured to the extent that the insureds (i.e. citizens in a jurisdiction in which our proposal operates) do not control the weather or the climate immediately preceding or at the time of the loss. Needless to say, the impetus for this proposal is loss-causing human interference with climate, but even attributable causation in this sense is well short of control of the climate.

(3) The peril must produce a loss definite in time and amount. The insurer must be able to verify the loss promptly and measure its magnitude.

Meeting this standard is feasible. Applying the FAR method requires careful definition of an extreme weather event in question and so losses associated with the event should also be definable. As with standard (1) above, there may be opportunity to constrain definition of losses with regard to time and amount of compensation. Climate change would need to be treated as an attributable cause of losses as opposed to non-climate variables that may ameliorate or exacerbate losses. One example would be the existence and adequacy of building codes. Whilst Allen et al. (2007) are careful to note that the FAR method does not address this, a compensation scheme funded by a carbon price that reflects anticipated financial losses would need to do so.

Verifying and measuring losses would not necessarily be overly onerous. Various parametric triggers are used to initiate timely access to insurance funds after weather catastrophes (Agrawala and Fankhauser 2008). Parametric triggers link insurance cover to precisely and transparently defined severity of natural catastrophes, for example, magnitude of earthquakes, wind velocity or air pressure for windstorm (Munich Re 2001: 7). The main advantage of parametric insurance is it allows rapid claim settlement. The main disadvantage is that the loss may differ substantially from the available cover. Significant disparity between assumed and actual cover also entails reputational risk for insurance providers (Maynard 2008).

The Caribbean Catastrophe Risk Insurance Facility (CCRIF), launched in 2006 in the wake of Hurricane Ivan 2 years earlier, is an example of insurance cover using a parametric trigger to allow rapid compensatory payments in the immediate aftermath of disaster. The CCRIF was established through the cooperation of the World Bank and the Heads of Government of the Caribbean Community and provides participating governments with immediate access to funds if hit by a natural disaster, until other sources of financing become available (Maynard 2008; CCRIF 2009).

(4) The insured group of risks must not be exposed to an incalculable catastrophe hazard. There must not be a significant concentration of values in vulnerable areas.

Our proposal does not fulfil this standard of insurability. Dangerous anthropogenic climate change as a globally coherent phenomenon is an unprecedented and incalculable catastrophic hazard. Instead, this proposal seeks to return and retain the Earth system to a familiar and stable state such that climate risks remain calculable.

(5) The premium must be reasonable in relation to the potential financial loss (priced to attract purchasers) and, simultaneously, actuarially sound to cover the losses while providing for insurer solvency.

Our proposal also does not fulfil this standard. The premium embodied in the carbon price in this proposal must be sufficient for insurer solvency and for anticipated liabilities. Affordability is a secondary issue: either anticipated liabilities on the basis of emissions volumes are affordable, or emissions volumes must drop until anticipated liabilities become affordable. We suggest affordability of emissions is dependent on achieving and maintaining emissions levels consistent with returning and retaining the Earth system to a familiar and stable state: the proposal's ambition emphasises mitigation rather than adaptation.

We argue that non-compliance of our proposal with the standards of insurability is justifiable. The proposal draws on insurance techniques to eliminate climate risk, rather than simply insure against it.

Moral hazard

Our proposal also raises challenging questions in relation to moral hazard. Moral hazard traditionally refers to the potential for insurance coverage to encourage insureds to take risks they would not otherwise take, or in other ways profit from access to insurance (Denenberg et al. 1964; Kunreuther 1998; Mills et al. 2001). Parsons (2003) describes this as 'moral hazard in the classic sense' and 'policyholder hazard' (p. 448), before extending the analysis of moral hazard associated with the existence of insurance to include 'claimant hazard' (relating to the behaviour of third parties potentially injured by insureds, for example by colluding with insureds to profit from insureds' coverage), 'jurisprudential hazard' (relating to the behaviour of lawmakers in legislatures and courts of law, for example by changing liability provisions retrospectively), and 'underwriting hazard' (relating to the behaviour of underwriters, for example lowering normal insurability standards in relation to some long-tail liabilities under some circumstances because substantial claims will likely not be received for many years) (Parsons 2003). This proposal raises very complex moral hazard issues through its novelty and through its potential spatial and temporal scales of operation (for example, across multiple states and therefore multiple legal jurisdictions, and across generations). A thorough exploration towards overcoming the moral hazard challenges our proposal generates is beyond the scope of this paper.

The creation of a substantial compensation fund carries moral hazards also: premium income and accumulated reserves are vulnerable to being exploited for purposes other than for which they are designed (Walker 2007). As noted elsewhere, this proposal calls for the creation of a very substantial compensation fund to be managed over an extended period. Thus there is the potential for pressure to be brought to bear for accumulated funds to be used for purposes other than for which they were collected, for example, for immediate climate emergency relief rather than losses attributable to earlier emissions.

Nevertheless large funds can and are accumulated and managed, for example sovereign wealth funds (Devlin and Brummitt 2007; Lyons 2008). Our argument is not that managing large sums is straightforward, simply that whilst clearly challenging, large funds set aside for accumulating liabilities have been managed over decadal timescales. Sovereign wealth funds (SWFs) may provide a model of long-term, strategic fund accumulation and management that could be modified for our proposal. SWFs, in some instances dating back more than 50 years, are examples of government-created and owned large-scale capital accumulation funds, often for the purpose of intergenerational wealth transfer, for example, for meeting accumulated pension liabilities (Devlin and Brummitt 2007). SWFs are managed either by states or by fund managers on behalf of states. SWFs have attracted increasing attention in recent years (Johnson 2007; Epstein and Rose 2009), in part because of fears for the potential for SWFs to be used as vehicles by foreign states to gain control over key domestic sectors, stoked by the recent rapid increase in SWF holdings: from US$500 billion in 1990 to around US$2.2 trillion in 2007, and with the potential to reach in excess of US$13 trillion within a decade (Lyons 2008). Governance arrangements for the multilateral development banks such as the World Bank Group potentially also offer lessons for the structure and management of our proposal's compensation fund.

Consistencies with existing forms of insurance

Our proposal shares a number of consistencies with existing forms of insurance and these are identified below.

- Use of insurance in support of public policy goals.

Governments use social insurance in support of public policy goals. The welfare state is a primary example (Phelan et al. 2008). Mitigating climate change by cutting CO_2e emissions is also a public policy goal that supports public welfare, albeit at global rather than national scale.

- Heavy government regulation of insurance sectors.

Governments regulate insurance sectors heavily to ensure (i) financial stability and viability of the sector, and (ii) ongoing public access to insurance. Insurance firm failures are uncommon events with repercussions that ripple through socio-economic systems (Commonwealth of Australia (HIH Royal Commission) and Owen 2003).

- Direct government engagement in insurance systems.

Governments engage directly in insurance systems to ensure system operation and effectiveness. Common examples of government engagement in insurance systems are legislating to ensure provision of workers' compensation insurance in workplaces and third party injury insurance on roads (Phelan et al. 2008). Governments legislate to ensure that (i) a small number of insurers may and do provide such cover, and (ii) that employers (in the case of workers' compensation insurance) and vehicle owners (in the case of third party personal injury insurance) are required to buy appropriate cover. In many cases governments also provide insurance directly. Common examples of governments as direct insurance providers are welfare states noted above and export credit insurance (Haufler 1997; Norlen and Phelan 2002; Phelan et al. 2008).

- Some forms of insurance provision operate at large temporal and spatial scales.

First, insurance houses are some of the longest established human organisations (Supple 1984; Westall 1984). Second, whilst subject to short-term pressures of business cycles, some have experience in planning and operating over substantially longer timeframes. Life insurers for example, are required to manage received premiums to ensure availability of funds when claims are made well in the future. The current proposal is consistent with operating over timeframes at this scale. Large reinsurers (and some insurers) operate at global scale, across multiple legal jurisdictions and with exposure to multiple risks. Our proposal therefore is consistent with aspects of existing reinsurance markets.

- Capacity for adaptive responses to changing circumstances.

Our proposal is an adaptive approach to climate change mitigation. Resetting carbon prices annually allows for prices informed by continually evolving climate and loss modelling. This is similar to standard practice for reinsurance contracts where annual terms allow for changes in risk assessment and changes in prices (as well as a limit to reinsurers' exposure to unanticipated liabilities).

Advantages over existing approaches

The primary advantage of our proposal over other current approaches to price greenhouse gas emissions is that our proposal supports deep cuts in emissions. It does this in two ways. First, our proposal operationalises the scientific–technical capacity to price near future losses attributable to current emissions. Second, through the creating of a new, heavily regulated and very large market, our proposal provides the political–economic impetus for both reinsurers and states to protect newly created and substantial financial stakes in near future climate stability. These two aspects of our proposal, together with ancillary aspects, provide a mechanism to create limits in the global economy consistent with Earth system limits.

Proposed and currently operating carbon taxes and ETSs are not designed to deliver deep cuts in emissions and have not done so. A market mechanism with any prospects at all for achieving deep cuts in emissions sufficient to avoid dangerous anthropogenic climate change requires carbon prices anchored to strategically important ecological constraints rather than carbon prices overwhelmed by immediate political and economic concerns.

A secondary advantage of the current proposal is that it provides a degree of stability to both carbon prices and emissions volumes. The liability link, combined with the FAR method puts a floor under both price and volumes: states or reinsurers, when accepting payment for permission to emit, are also accepting a liability for anticipated future damages. Sudden drops in price that have the effect of undermining market confidence as experienced in the European Union ETS in recent years are extremely unlikely. Changes in the price will reflect changes in evolving understanding of the Earth system.

Our proposal provides a stable (not static) price and a stable (not rigid) cap on volumes. Within Earth system limits, the price and the cap inform each other. As volumes rise, so do liabilities and therefore so does price. As volumes drop, so do liabilities, and price also. As noted earlier, climate change means changes in the Earth system and the evolving relationship between that system and smaller component systems, and scientific understanding of those systems and their relationships. This demands a reflexive mitigation response (Phelan et al. forthcoming). Additionally, mitigation policies and action will evolve over time.

Key elements of reflexive systems proposal

There are many permutations of how this proposal could be applied. In this section we limit our focus to three closely interlinked and key elements: (i) continuously modelling risks and setting carbon prices; (ii) issuing permissions to emit; and (iii) making and paying claims. For each element we raise a number of important questions that require further investigation.

Continuously modelling risks and setting prices

Creating sound, stable and ecologically realistic carbon prices generated by drawing on aspects of insurance systems requires reinsurers and loss modellers to continuously model future financial losses potentially attributable to current CO_2e emissions. This raises many questions about the scope of our proposal overall and about key aspects of our proposal's operation. Significant issues regarding the scientific, social and political–economic feasibility of our proposal are discussed below.

- Temporal scales to be applied.

The timeframe for avoidance of dangerous anthropogenic climate change is uncertain, if indeed it is not already too late (Hansen et al. 2008). Allen et al. (2007) argue that over the next couple of decades or so scientists can with high confidence determine probabilistic attribution of anthropogenic climate change to large-scale damaging events. It is well within this timeframe that significant cuts in emissions must be made, even though damages will likely continue to be sustained beyond that period. However, this analysis has yet to grapple with the vexed question of an equitable treatment of financial responsibility for risks and losses attributable to historical emissions: even where technical challenges can be overcome, ethical dilemmas remain unresolved. All nations currently face climate change losses resulting from emissions associated from the development paths followed by a subset of industrialised countries. Low-income countries that have contributed the least to climate change in historical and contemporary terms are particularly vulnerable to climate change impacts now and in the future.

One contribution towards resolving disparities in historical emissions in the context of this proposal would be for governments to contribute initial capital to the compensation fund on the basis of their historical emissions, estimated at 348 billion tons since 1850 (Global Carbon Project 2008a). Applying recent carbon prices (i.e. US$26 per ton) suggests starting capital at a little over US$9 trillion. Contributing initial capital to a compensation fund on this basis models other forms of comprehensive insurance cover, for example, universal public health insurance: access to health care is on the basis of citizenship and financed through tax revenues levied on the basis of capacity to pay.

- Spatial scales to be applied.

The most appropriate geographic scale for this proposal to operate is global. However, this prompts questions of how to accommodate industrialised and low income countries fairly as well as operationalising our proposal across multiple jurisdictions and very varied cultural contexts. Conceptualising our proposal globally comprehensively encompasses all the diffused sources of anthropogenic CO_2e emissions into the Earth system, and in turn, the global distribution of resulting financial losses. Clearly our proposal demands a level of international cooperation appropriate for a global threat. Most current ETSs are national and regional, not global. Carbon taxes are national and sub-national. A less comprehensive (and interim) approach might also be possible on a proportional basis with respect to CO_2e emissions and damages, as well as rights to make claims.

- Definitions of insured risks including type, scale and location of damages.

This proposal requires limits on what will and will not be insurable. In the agricultural sector, for example, some climate-implicated losses are caused by sudden shocks, for example hail damage. Others are caused by long-term stresses, for example droughts. Others may be permanent, for example changes in suitability of areas for particular agricultural crops. Even where attribution is technically possible, significant questions remain about what loss-causing weather events and trends will and will not be claimable. The more comprehensive our proposal, the greater its effectiveness and therefore the greater its strategic worth.

- Application of the FAR method to various damaging events.

Our proposal prompts the question as to which scenarios the FAR method is technically feasible. To date the FAR method has been applied to large spatial scale extreme weather events: heatwaves and floods. In principle, the FAR method could be applied to smaller events (Allen et al. 2007: 1393). As noted earlier, others have since applied a variation of the FAR method on smaller scale (Jaeger et al. 2008). The FAR method has not yet been applied to large temporal scale events such as droughts, weather trends or climatic changes, such as temporary or permanent shifts in viable agricultural zones.

- Social acceptance of scientific methodology consensus.

Allen et al. (2007) ask the legal community if scientific consensus around method will be accepted into their fold. This proposal also requires social acceptance of evolving scientific methodology reflected in legislation, international agreements and market operations.

- Capacity for continuous modelling.

Climate modelling research is continuous and ongoing. So too is loss modelling. Pricing risks accurately requires ongoing access to information about changes in climate, insurable risks and assets.

Permission to emit

A small number of regulated large reinsurers would be licensed by governments to issue permissions to emit. Under this proposal, issuing and receiving payment for permission to pollute entails creating, pricing and accepting an attached near future financial liability. Businesses and other organisations wishing to emit CO_2e would be required to purchase permission to emit to cover anticipated emissions. An ecologically effective cap on total emissions would be supported by the use of insurance techniques providing upward pressure on the carbon price. Under this proposal, a small number of reinsurers licensed by governments would be required to retain and manage funds to ensure their availability to compensate future claims. Making and paying claims from such funds is addressed below and we return later to the management of such funds and the opportunities they provide.

Making and paying claims

The primary purpose of our proposal is mitigating climate change. An important related purpose is collecting and managing funds to ensure availability of funds when attributable climate impact liabilities arise. Making and paying claims presents several challenges. First, eligibility to claim needs definition; one option would be to limit potential claimants to national governments who would make claims in the name of their citizens. Second, triggers for paying claims eligible for compensation would need definition and, as noted above, there are many index-based triggers available in existing insurance arrangements, for example for extreme weather events and agriculture. Third, the amount of compensation to be allocated needs clear definition. The fractional results generated by the FAR method (i.e. that anthropogenic climate change is most likely only ever a partial contributor to the probability of a damaging event occurring) are consistent with partial rather than comprehensive restitution of losses. Allen et al. (2007: 1357) are careful to note also that the FAR method addresses climate variables only, and does not address questions around land use decisions such as allowing or disallowing building in vulnerable areas, which may contribute to or prevent financial losses.

Important ancillary opportunities

Our proposal creates important ancillary opportunities in three overlapping areas: (i) intergenerational equity; (ii) indirect support for other mitigation policies and action; and (iii) intragenerational equity. These are associated with our proposal's creation and management of a fund from which to pay claims.[7] Our proposal has the potential to create an extremely substantial fund with several necessary purposes. The fund would be managed principally to ensure its growth and future availability to fund anticipated claims as well as generate sufficient interest income to cover ongoing administrative costs. The fund's growth would be dependent on investments and these would be at minimum greenhouse neutral, consistent with our proposal's overall mitigation goal. Adopting an ethical investment approach and prioritising investment in renewable energy technologies would also further our proposal's overall mitigation goal. Finally, a proportion of income generated by the fund would be used to finance the transfer and diffusion of renewable energy technology on non-commercial terms from industrialised to low income countries.

Intergenerational equity: compensating our children's losses

Operational at a global scale, the fund could well dwarf existing international sources of loans and insurance, such as the International Monetary Fund, the World Bank Group and the regional development banks. In and of itself this is a profound step in support of intergenerational equity and is novel in its approach to pricing CO_2e emissions. Climate change impacts caused by earlier emissions are already manifest. Yet near future generations (children of people alive today) are likely to suffer even greater financial losses as a result of current emissions. This is already established and the ethics of neither acknowledging not acting on this awareness are unjustifiable, unattractive and insupportable. Whilst the specifics of what damages will manifest cannot be predicted, it is certain that the financial costs of near future climate change impacts and adaptation measures will be high. Stern (2006), for example, applies a cost benefit analysis approach and estimates the costs of inaction as up to 20-times greater than mitigating climate change, where mitigation is costed at 1% of global annual Gross Domestic Product (GDP), and inaction at up to 20% of GDP annually in perpetuity.

Mitigation: rapidly decarbonising the global economy

Our proposal's primary purpose is to drive down CO_2e emissions in support of climate change mitigation by generating ecologically realistic prices for CO_2e emissions. In so doing, our proposal reinforces other well-designed policy measures and actions to cut emissions, and acts to counter policy measures and actions that are ineffective or obstructionist. As such, our proposal contributes both directly and indirectly to climate change mitigation.

The fund created by our proposal would also drive climate change mitigation in several ways. Managing the fund in a manner consistent with its purpose would mean an investment strategy that generates no net increase in emissions. The sheer magnitude of the fund combined with its purpose opens substantial opportunities for investment in renewable energy technologies to replace and augment large-scale decommissioning of existing fossil fuel energy infrastructure. Investment funds would be available for research and development through commercialisation and proliferation development stages.

Intragenerational equity: non-commercial financing for renewable energy technology diffusion

A portion of the investment income generated by the fund could be used to finance on non-commercial terms the transfer and proliferation of renewable energy technologies in low-income countries. This would be an act of intragenerational equity, consistent with the aims and objectives of the United Nations Framework Convention on Climate Change; specifically it addresses Article 4, which contains the principle of 'common but differentiated responsibilities,' and the commitment of industrialised country signatories to 'promote, facilitate and finance ... the transfer of ... environmentally sound technologies' (United Nations 1992). Populations of low-income countries (non- and recently industrialised countries) have contributed least to the problem and are most vulnerable to climate change impacts.

Discussion and future directions

The climate change challenge is manifest at very large temporal and spatial scales and at very great magnitude. Climate change has already been labelled by economists as the 'greatest market failure ever witnessed' (Stern 2006) and as a 'diabolical policy challenge' (Garnaut 2008). Existing carbon taxes and ETS frameworks for pricing CO_2e emissions have been unable to generate carbon prices that reflect the biogeophysical limits of the Earth system. We argue that they are not equipped to do so. Thinking and acting at Earth system scale and with the degree of uncertainty inherent in a globally coherent phenomenon such as climate change is an unprecedented challenge for policymakers. Human social systems struggle with thresholds, tipping points and cascading effects typical of complex adaptive systems, including the Earth system (Duit and Galaz 2008; Phelan et al. 2009a).

This paper has explored the rationale and potential for applying insurance techniques to generate carbon prices that reflect the dependence of the global economy on Earth system stability. The FAR method described in this proposal provides the scientific–technical capability to determine probabilistic attribution of financial losses to earlier anthropogenic CO_2e emissions. The liability mechanism described in this proposal provides a form of financial discipline as part of its contribution to effective limitations in emissions. It does so by creating a political economic driver for ecologically realistic carbon prices: a liability that is then allocated to reinsurers, backed by governments, creating a specific and measurable financial interest in future climate stability that can be strategically defined and defended. The central feature of this proposal is its potential to drive cuts in emissions sufficient to avoid dangerous anthropogenic climate change. Our proposal does this by using insurance systems to more directly account for interaction between the global economy and the Earth system. Our proposal is an example of reflexive mitigation (Phelan et al. forthcoming) and a departure from current approaches to carbon pricing. However, our proposal is compatible with a number of aspects of existing forms of insurance. Under our proposal, the price ascribed to carbon shares similarities with insurance premiums.

Our proposal described in this paper uniquely provides the scientific–technical capacity and the political–economic incentive to shift the anchor point for carbon prices away from immediate political and economic considerations and nearer to strategic ecological requirements for Earth system stability: the balance is shifted to emphasise changes in the global economy necessary to avoid dangerous anthropogenic climate change over estimations of what is politically and economically feasible or desirable. Our proposal identifies a number of important challenges regarding feasibility and operation as well as directions for further research.

The following question can be asked: Is this proposal for an insurance basis for carbon prices feasible? Although clearly a challenge, a better question could be: What if it is not feasible? What does it say about the nature and magnitude of the risk if human social systems cannot provide themselves with insurance against dangerous anthropogenic climate change? A world with risks but without insurance to manage those risks is possible – much of the world's population is already living in such conditions. Attempting to adapt to changing conditions is also possible, even perhaps where the Earth system has been pushed outside of its familiar stable state. However adaptation with grace (adaptation undertaken in an orderly and planned manner, embodying important principles of justice and equity, and with some hope of longevity) is dependent on successful climate change mitigation (Phelan et al. forthcoming). Possible futures are more or less desirable. Simply adapting to circumstances as we cause them to change, without thinking as to how we are changing them, is a passive response and less than we are capable of. Creating a future that is sustainable and equitable is at once an inspirational vision, a strategic goal to which we can aim and perhaps our only viable option.

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Notes

1. CO_2e (equivalent carbon dioxide emissions) is a 'standard and useful metric for comparing emissions of different greenhouse gases' (IPCC 2007b: 945). In this paper, in the interests of flow, we use 'emissions', 'CO_2e emissions', 'carbon emissions', 'carbon' and 'greenhouse gases' interchangeably.
2. Carbon is also priced as part of assessing the anticipated benefits and costs of proposed projects and policies, for example infrastructure developments such as highways and airports. Similar to market-based instruments, approaches such as shadow price and social cost of carbon (Stanton and Ackerman 2008) are aimed at internalising the externality of carbon emissions. The approach to pricing carbon presented in this paper may be applicable and useful in these contexts also but is not considered here.
3. Washington et al. (2009) begin by conceding that significant warming this century cannot be avoided. Their objective is to model emissions reductions necessary to avoid the most serious climate change impacts. On this basis Washington et al. (2009: 5) suggest deep cuts in emissions in the order of 70% on today's levels by 2100 would still allow stabilisation of the Earth system, albeit at a warmer temperature.
4. 'Transient Climate Response' is defined as 'the warming we should expect at the time of carbon dioxide doubling – around year 70 – if carbon dioxide levels were to increase at 1% per year, starting with a climate in equilibrium' (Allen et al. 2007: 1353–1400). The alternative approach uses the more common stabilisation scenarios, about which there is less scientific consensus. See Frame et al. (2006) for a detailed discussion.
5. The FAR method is not applicable to future events: it is not a predictive tool. The FAR method provides a probabilistic assessment after the fact. Allen et al. (2007: 1390) however suggest as a future research direction exploring the predictive application of FAR method, i.e. attempting to catalogue and define damaging weather events before they occur.
6. Point Carbon (2009) calculates a 'weighted average world carbon price of €19 ([US]$26) per tonne CO_2e in 2008', and notes that in 2008, '[t]he world's carbon market exchanged 4.9 billion tonnes (Gt) CO_2 equivalent in … worth an estimated US$125bn'.
7. Others have also proposed climate change-linked funds, for example the 'Earth Atmospheric Trust.' See Barnes et al. (2008).

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7. From application to reflection: Feedbacks for theory development

7.1 Introduction

This chapter is based on paper E 'Blood on the floor: Political economy of climate crisis in the Earth system'. The chapter represents a shift to reflection on theory, and makes this transition in the light of the application of theory in earlier chapters, aimed at problem identification and characterisation, and solution creation. Chapter Seven steps beyond the exploration of the insurance system-anthropogenic climate change relationship to reflect on the use of theory in that exploration. This chapter highlights and reflects on the political challenge that anthropogenic climate change mitigation entails. The chapter argues that resilience approaches – one form of complex adaptive systems approaches as applied to social-ecological systems (SESs) – are insufficient for effectively theorising political conflict and change, particularly in times of systemic crisis in SESs.

This chapter suggests that linking CASs approaches with the critical political economy theory area may improve CASs approaches' capacity to theorise political contestation and social change processes in SESs. The chapter presents a new conceptual framework that brings together resilience approaches to SESs and critical neo-Gramscian political economy. The chapter concludes with an application of the conceptual framework to better explain climate crisis in the Earth system: both the character of the threat anthropogenic climate change presents human societies, and the challenge of achieving equitable and just mitigation.

This chapter moves the scale of analysis from the insurance system and its relationship with anthropogenic climate change, to focus more directly on the broader political economic system (or human-social elements of the Earth system) in which the insurance system is nested. While the relationship between anthropogenic climate change and the insurance system is the focus of the earlier chapters in which the complex adaptive systems approach is applied, anthropogenic climate change threatens human societies generally. Shifting focus to human societies and the SES in which they are located provides a better vantage point from which to reflect on the merits and limitations of the resilience approach developed specifically to address SESs, *i.e.* complex adaptive systems comprising co-evolving human-social and ecological elements.

7.2 Contribution of paper E in the context of the overall thesis

Table 7.1: Contribution of paper E in the context of the overall thesis

Thick borders identify the research questions to which paper E responds.

1	**Research aim: what does anthropogenic climate change mean for the insurance system?**	
1.a	Research question: If anthropogenic climate change presents a threat to the insurance system, what is the character of that threat, *i.e.* is the threat temporary, intermittent, permanent, strategic, or existential?	
	Response: • *Permanent, strategic and possibly existential.*	*Locations:* • *Chapter 3/paper A; Chapter 4/paper B; and Chapter 5/paper C.*
1.b	Research question: To what extent might anthropogenic climate change present an opportunity to the insurance system?	
	Responses: • *Limited and short-term if at all in the absence of effective mitigation. Ultimately anthropogenic climate change threatens the viability of the insurance system as currently structured.* • *In contrast anthropogenic climate change mitigation presents a theoretical opportunity to the insurance system.*	*Locations:* • *Chapter 4/paper B; Chapter 5/paper C; and* • *Chapter 6/paper D.*
2	**Research aim: how might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?**	
2.a	Research question: How has the insurance system approached anthropogenic climate change to date?	
	Response: • *Strongest insurance system responses to anthropogenic climate change to date are generally adaptive and weakly mitigative.*	*Location:* • *Chapter 4/paper B*
2.b	Research question: If the insurance system has not adopted a strong mitigative stance towards anthropogenic climate change, is there theoretical potential for it to do so?	
	Response: • *Yes: theoretically such potential exists.*	*Locations:* • *Chapter 5/paper C; and Chapter 6/paper D.*
3	**Research aim: how might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?**	
3.a	Research question: What theory limitations are revealed by the application of a CASs approach to the anthropogenic climate change-insurance system relationship?	
	Response: • *Limitations with regard to norms and power*	*Location:* • *Chapter 7/paper E*
3.b	Research question: If there are limitations to CASs approaches, is there potential to overcome them through linking CASs approaches with other theory areas?	
	Response: • *Yes: for example by drawing on critical political economy theory.*	*Location:* • *Chapter 7/paper E*

7.3 Paper E: 'Blood on the floor: Political economy of climate crisis in the Earth system'

Paper:

Phelan, L., Taplin, R., & Henderson-Sellers, A. Blood on the floor: Political economy of climate crisis in the Earth system. Submitted April 2010 to *Climatic Change*.

An earlier iteration of this paper was:

Phelan L, Henderson-Sellers A, Taplin R. 2010. Political economy of social-ecological systems in crisis: Sharpening theory tools for praxis. *International Studies Association 2010 Annual Convention: Theory vs. policy?: Connecting scholars and practitioners*. New Orleans, 17-20 February. [Oral presentation and available online at http://www.allacademic.com/meta/p414246_index.html].

Blood on the floor: Political economy of climate crisis in the Earth system

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Blood on the floor: Political economy of climate crisis in the Earth system

Abstract

The Earth system is a complex adaptive system, characterised by non-linear change with significant capacity for surprise. In times of systemic crisis, such as dangerous anthropogenic climate change, perverse resilience (e.g. structural power of fossil fuel interests in the global economy) can threaten overall system integrity. Resilience approaches describe social-ecological systems but neglect the significance of power relations in human societies. Critical political economic analysis recognises climate change as a threat with significant political economic characteristics and implications. However key dimensions of climate change as a globally coherent phenomenon, including the important implications of Earth system dynamism and non-linear change, can remain unrecognised, mischaracterised or underestimated. This paper builds theory by linking key concepts from neo-Gramscian political economic analysis with resilience approaches reflecting social-ecological system dynamism. An explicitly political approach to systemic change would be uncontroversial in the political economy arena, but is more unusual in the context of resilience approaches to social-ecological systems. The objective is to generate a new conceptual framework to improve understanding of the role of politics in social-ecological systems. We use climate change mitigation as a case study to contrast the whole-of-system resilience view with the conflict-within-the-system political economy focus. This perspective reveals climate change as a globally coherent environmental injustice originating in the global economy, a subsystem of the Earth system. We demonstrate the value of linking neo-Gramscian approaches to political economy with resilience approaches to social-ecological systems and use this new framework to explore potential for contesting perverse resilience in social-ecological systems in crisis.

Keywords

social-ecological systems; climate change; adaptive social change; neo-Gramscian; political economy; resilience

Blood on the floor: Political economy of climate crisis in the Earth system

1. The sustainability paradox: Familiar stability depends on radical change

This paper is a first order attempt to link the complex adaptive systems and political economy theory areas in the context of climate change. Coupling resilience approaches (Walker *et al.* 2004, p.xi) to social-ecological systems and neo-Gramscian international political economy theory (Levy and Newell 2005) gives new insights into the political dynamism of social-ecological systems in crisis. In doing this we generate a new conceptual framework with the potential to illuminate effective, equitable and just responses to Earth system failure attributable to anthropogenic climate change.

The Earth system can be conceptualized as a social-ecological system, i.e. a complex adaptive system comprising human-social and ecological elements (Berkes and Folke 1998, p.65). Resilience approaches to social-ecological systems focus on maintaining system function and stability (Walker and Salt 2006). However, in times of systemic crisis, perverse resilience (Gallopín 1997; in Faye *et al.* 1999, p.118) i.e. resilience internal to the system that is at odds with the sustainability of the system, can threaten overall system integrity. In this paper, we reflect on the Earth system as a social-ecological system, and the global economy a subsystem nested within it (Phelan *et al.* 2010b).

The global economy functions currently in a way that is inconsistent with the limits of the Earth system and is threatening the familiar (to humans and our civilizations) stable state of the Earth system (Hansen *et al.* 2005; Rockström *et al.* 2009). The Earth system faces multiple crises, such as species diversity loss and the collapse of resource bases and ecosystem services (Millenium Ecosystem Assessment 2005). Anthropogenic climate change (IPCC 2007a) is a key manifestation of the inconsistencies between the global economy and the Earth system, and a focus of this paper. Understanding the Earth as a complex adaptive system highlights an Earth system characterised by non-linear change and with capacity for surprise (Schneider 2004; Schellnhuber *et al.* 2006; Hansen 2007; Rahmstorf *et al.* 2007; Lenton *et al.* 2008). The implications of climate change for human societies are profound and highly uncertain (Hansen *et al.* 2005).

The relationship between the Earth system and the global economy as a subsystem gives what we term the sustainability paradox: maintaining the desirable, familiar stability of the Earth system overall requires radical change in the human social subsystem(s) nested within it. The sustainability paradox (at planetary and other scales) articulates in systems terms the pressing ecological need for radical societal change to ensure ongoing viability of human society's ecological foundations. This articulation is consistent with many earlier calls (Carson 1963;

Meadows and Club of Rome 1972; Schneider 1976; Catton Jr 1980; Daly 1982; Meadows *et al.* 2004).

Both climate change and its mitigation are anthropogenic, i.e. anchored in human-social system elements of the Earth system. Resilience approaches to social-ecological systems explain well the threat that climate change presents human societies, for example the notion of impacts cascading across domains and scales (Galaz *et al.* 2006). However, the theoretical approach struggles to explain political economic dynamism within human-social systems, or to provide options for mitigation responses that fully reflect political as well as Earth system constraints.

In the remainder of the paper we further explore resilience, complex adaptive systems, and critical political economy in relation to climate change. Section two identifies two limitations to resilience approaches as explanatory of conflict in human-dominated social-ecological systems such as the Earth system. In section three, we propose a conceptual linkage between resilience and hegemony to better account for political-economic dynamism in social-ecological systems. Section four applies the linked complex adaptive systems-political economy framework to (i) better explain climate crisis as a social-ecological phenomenon of the Earth system and (ii) inform effective, equitable and just political change in support of climate change mitigation. Section five concludes the paper.

2. Two limitations of resilience approaches to social-ecological systems: Uncritical engagement with norms and the bloodless treatment of power

The complexity approach (Bradbury 2006; Waltner-Toews *et al.* 2008) is still in its infancy and 'tends to employ an eclectic collection of theories and methodologies designed to deepen our limited understanding of the properties of complex adaptive systems' (Finnigan 2006). The orientation remains fluid to some extent, and is yet to crystallise into a clearly articulated theory.[1] Complex adaptive systems (CAS) approaches are a subset of systems approaches and have been applied in a range of disciplines (Hartvigsen *et al.* 1998; Milne 1998; Anderson *et al.* 2005). Kay (2008) traces the origins of modern systems thinking to von Bertalanffy's work in evolutionary biology beginning in the 1920s and his general systems theory (Bertalanffy 1968), and notes the spread of systems approaches in fields as diverse as anthropology, physiology, mathematical biology, cybernetics and management sciences. Whilst systems thinking originated in natural systems fields, human and mechanical systems also adopted the approach, which concerns itself

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[1] CAS researchers continue to be more comfortable referring to CASs and CAS *approaches* rather than CAS *theory*. See for example (Levin 1998). Similarly, resilience researchers continue to refer to *resilience thinking* (Walker and Salt 2006) or in other somewhat tentative manners (Walker *et al.* 2006a; Walker *et al.* 2006b) rather than to a *theory* of resilience.

with ‘connectedness, context, and feedback… interactions, relationships and patterns… [u]nderstanding comes from looking at how… parts operate together rather than from teasing them apart’ (Kay 2008, p.7). Kay (2008, p.8) describes complex systems thinking as the ‘grandchild of von Bertalanffy’s general systems theory’, emerging in the wake of new science of the 1970s including nonequilibrium thermodynamics, complexity approaches and chaos theory.

Social-ecological systems (SESs) are CASs with human-social and ecological elements. CAS approaches as applied to social-ecological systems are still very much in flux and continuing to be advanced (Gallopín 2006; Janssen and Ostrom 2006; Walker *et al.* 2006a). CAS approaches as applied to human social systems and their environments are consistent with a ‘humans in the environment’ perspective. At the planetary scale, Lovelock’s ‘Gaia’ (1979; 1988; 2006; 2007) conceptualises the Earth system inclusive of humans and our societies. Both Lovelock’s ‘Gaia’ and Crutzen and Stoermer’s ‘anthropocene’ (Crutzen and Stoermer 2000; Crutzen 2002) acknowledge the Earth system as a social-ecological system, i.e. a complex adaptive system comprising human-social and ecological elements. Crutzen’s and Stoermer’s ‘anthropocene’ emphasises humanity’s current dominance as the driving force of change in the Earth system.

The concept of resilience has evolved, together with vulnerability and adaptive capacity, to provide a substantive foundation for what have come to be termed resilience approaches to social-ecological systems (Adger 2006; Folke 2006; Gallopín 2006; Smit and Wandel 2006). Resilience approaches may usefully inform effective, equitable and just societal responses to the sustainability paradox defined above. However, to do so may require linking resilience approaches with more established theoretical analyses of political dynamism in human-social systems that better account for conflicts arising from incompatible and even irreconcilable human interests and values. Here we explore two important aspects of resilience approaches to social-ecological systems that underscore the theoretical limitations of the approach as currently applied to: (i) an uncritical and non-transparent engagement with norms and values; and (ii) a negligent or bloodless treatment of power in human-social systems. In short, resilience approaches to social-ecological systems struggle to respond with normative precision to questions of what (if any) systemic change might be desirable, for whom, and why, and how such change might be achieved. Consistent with this perspective, a symposium held in the UK in late 2008 titled ‘Re-framing resilience’ identified several current thematic challenges and opportunities in progressing resilience approaches (Leach 2008, pp.14-15). Ideals such as justice and equity, widely accepted as important in human societies, tend not be addressed explicitly in resilience approaches to broader social-ecological systems (Leach 2008).

2.1 Acknowledging norms and values

Uncritical and non-transparent engagement with norms and values is problematic for theoretical analyses of humans and our societies. David Hume argued in 1739 that drawing prescriptive conclusions from descriptive premises is a *non sequitur*: an 'ought' does not follow from an 'is' (Hume 2006 [1739]). With reference to climate change, neither the premise that warming of the climate system is unequivocal (IPCC 2007b, p.5), nor that '[m]ost of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations' (IPCC 2007b, p.10) automatically lead to the conclusion that we *ought* to mitigate and adapt to climate change.

Climate change mitigation and adaptation are both choices, as are the forms each may take. There is widespread support in general terms for climate change mitigation and adaptation, as expressed for example in the United Nations Framework Convention on Climate Change (UNFCCC) (United Nations 1992). Virtually all United Nations member states are ratified signatories to the UNFCCC. However, and as we discuss below, support for climate change mitigation, whilst widespread, is not universal, and, we suggest, will never be.[2] Specific forms of policy responses are also choices. Even where there is agreement on mitigation's desirability, proposals for achieving that objective may be inconsistent and even contradictory. Multiple policy approaches to mitigation and adaptation have been proposed and are being pursued in international, national and sub-national contexts.

Many working with resilience approaches to social-ecological systems have focussed on applying evolving resilience understanding towards more effective Earth system governance (e.g. Gunderson and Holling 2002; Folke 2006). Outcomes include practical examples of effective adaptive management of ecosystems (Olsson *et al.* 2007), continually evolving analyses of social-ecological systems (e.g. Folke *et al.* 2005; 2007; Young *et al.* 2008) and more integrative theory-building (e.g. Janssen and Ostrom 2006; Walker *et al.* 2006b).

Whilst useful towards better understanding of SESs, such approaches can lack a critical awareness, appearing at times to simply assume resilience is desirable. Similarly to the way the concept of sustainability has become stretched beyond its original meaning to become applied toward a variety of at times contradictory purposes (e.g. the *financial* sustainability of an otherwise ecologically, socially and economically unsustainable resource extraction project), the normative dimensions of resilience are complicated. As Lebel et al. (2006) ask: '[t]he resilience of what… [f]or whom?' Posing such questions highlights the often uncritical engagement of resilience approaches to normative dimensions of social-ecological crises.

[2] Neoliberal climate change denialism is vitriolic in part because the demands of effective climate change mitigation show up the limited ecological appropriateness of responses consistent with neoliberalism, i.e. market responses. As such the reality of climate change undermines the theoretical foundations of neoliberalism (Aly 2010, pp.84-93).

Perverse resilience (Gallopín 1997; in Faye *et al.* 1999, p.118) implies a more critical understanding of resilience and has been proposed to refer to resilience within a system that is undesirable to the extent that it is socially unjust, inconsistent with ecosystem health or threatens overall system viability (see for examples of usage Waltner-Toews 2004, p.79; School of Environmental Design and Rural Development 2005, p.7; Albrecht 2009). An example from Australia, in relation to as yet ineffective national policy and action responses to the threat of anthropogenic climate change, is the continuing perverse resilience of the coal industry in the Hunter Valley region (Evans 2008) and nationally (Hamilton 2001; Pearse 2007, 2009). However, development of the term remains limited and there is ample room for further definitional deliberation; in normative terms, both resilience and perverse resilience remain poorly conceptualised.

2.2 Addressing power relations

Resilience approaches to social-ecological systems also provide a bloodless or negligent treatment of power by not addressing power in human societies adequately. By bloodless we mean resilience approaches are yet to adequately reflect the reality of political contestation. Groups of humans in political economic systems often have interests and values that are contradictory, even incompatible, and in conflict with maintaining the familiar stability of the Earth system. We argue human society's continuing inability to successfully mitigate climate change reflects this scenario: the climate crisis remains intractable not because of climate system complexity, but because of the phenomenon's political and economic dimensions.

Resilience approaches to environmental governance are dominated by regional-scale case studies (e.g. Olsson 2006; Walker and Salt 2006). Walker et al. (2006b) cite numerous regional-scale case studies (e.g. lakes and wetlands, rangelands, irrigation systems and coral reefs) that have been important to the development and generalisation of the resilience approach. Narratives of success stories involve scenarios in which varied stakeholders concerned about a particular ecological feature or natural resource such as a lake come together and negotiate a sustainable management approach that all can live with (e.g. Olsson *et al.* 2007). However, climate change is a globally coherent phenomenon and in some respects quite a different proposition. All human communities are implicated in various ways and to varying extents with reference to both climate change causation and vulnerability to it. Effective, equitable and just mitigation requires explicit engagement with power relations internationally and internally to states and societies.

Resilience approaches accommodate the threat climate change presents to human societies as an anthropogenic phenomenon of the Earth system with impacts across system scales and domains. Resilience approaches also accommodate in technical terms the change necessary to ensure an effective response: the message from climate scientists for deep cuts in emissions and the retention of surviving carbon sinks such as forests has come through in relatively accessible language (IPCC 2001, 2007a; Hansen *et al.* 2008; Kerr 2009). As complex as the Earth system is, understanding about *what* constitutes effective mitigation is relatively straightforward: (i) rapid and deep cuts in emissions; and (ii) conservation and then expansion of surviving carbon sinks. The importance of Earth system stability for the continued viability of the Earth system as a habitat for humans is also reasonably straightforward in resilience terms. However, a grasp of the political challenges of effective, equitable and just mitigation remains elusive.

2.3 Critical inquiry and the view from political economy

The need to account for norms and power relations in social-ecological systems (SESs) provides an opportunity to call on the critical inquiry tradition. The term *critical* 'is deeply perverse in the plurality of connotations and interpretations (some of them contradictory) it provokes' (Brookfield 2005, p.11). We use critical inquiry (or theory) in this paper as it is applied to refer to a number of theoretical approaches aimed at 'fundamental political, economic, and cultural transformation of society'.[3] In that sense critical theory is distinct from the traditional liberal and conservative thought (Gottlieb 1999, p.ix). The distinction between traditional social theory and critical theory is

> a contrast between a research that seeks merely to understand and a research that challenges… between a research that reads the situation in terms of interaction and community and a research that reads it in terms of conflict and oppression… between a research that accepts the *status quo* and a research that seeks to bring about change (Crotty 1998, p.113).

Thinking critically in this sense is clearly 'an inherently political process' (Brookfield 2005, p.vii). We draw on the critical inquiry tradition to 'understand not just how the world is but also how it might be changed for the better' (Brookfield 2005, p.7), where 'better' is defined as achieving effective and just mitigation of anthropogenic climate change.

Political economy is concerned with 'political economic problems and policy issues', and is interdisciplinary in character because '[r]eal world phenomena do not fit neatly into boxes labelled 'economic', 'social, 'political', or 'cultural' (Stillwell 2002). Some political economy theorists are recognised as explicitly critical in their approach, including Antonio Gramsci, whose key idea of hegemony we draw on for this paper. With regard to anthropogenic climate change, political economy addresses questions of *why* effective mitigation is yet to be achieved (e.g.

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[3] Whilst 'critical theory' is often used to refer to the work of the Frankfurt School theorists such as Horkheimer, it also describes variations of Marxism and feminism, approaches drawing on Foucault and others. See (Crotty 1998, p.112-159; Gottlieb 1999; Merchant 1999, p.1-25; Brookfield 2005, p.1-65)

Paterson 2001), and also suggests limited opportunities and possibilities for achieving the necessary change (Levy and Newell 2002; 2005; Pearse and Stillwell 2008).

In contrast to the focus on the overall state of systems of resilience approaches to social-ecological systems, political economy brings focus to disparate interests of actors within the human-social system. Political economy accommodates the notions of interests (and values) that are in conflict and comparative differences in power relations leading to contested, contingent system stability (Levy and Newell 2002; 2005; Levy and Scully 2007). Newell (2008) for example in discussing the political economy of global environmental governance builds on earlier more general analyses of power and power relations (Cox 1987; Lukes 2005). In short, political economy analysis of environmental issues as addressed in human social systems (e.g. global environmental governance) focuses squarely on political contestation and dynamism.

Linking political economic analytical insights with complex adaptive systems approaches may sharpen accounts of norms and power in SESs. Political economy is not a replacement for resilience approaches to SESs: political economy is not equipped to describe or analyse with precision SESs in general and climate change as a phenomenon of the Earth system in particular (Phelan *et al.* forthcoming). Political economy can recognise climate change as a threat with significant political economic characteristics and implications. However, key dimensions of climate change as a globally coherent phenomenon, including the important implications of Earth system dynamism and non-linear change can remain unrecognised, mischaracterised or underestimated in political economy analyses (Phelan *et al.* forthcoming).

3. Coupling complex adaptive systems and political economy

Although not their stated intention, Levy & Newell's (2002; 2005) political economy approach to global environmental governance suggests potential for linking neo-Gramscian[4] international political economy theory and resilience approaches to SESs. In this section, we review theoretical consistencies and inconsistencies between the two approaches. For this paper we have adopted Levy and Newell's (2005) critical neo-Gramscian form of international political economy (IPE) analysis as applied to global environmental governance. We have arrived at this point through investigation of the relationship between insurance systems and the Earth system in the context of climate change (Phelan *et al.* 2010a; Phelan *et al.* forthcoming) and with

[4] Levy and Newell (2005, p.65) 'use the term "neo-Gramscian" in acknowledgement that [the] conceptual framework does not rely on Gramsci's writing in any doctrinaire sense and that it also owes intellectual debts elsewhere.'

reference to political-economic analyses of the insurance industry and other business sectors in global climate politics (Newell and Paterson 1998; Paterson 1999, 2001, 2005).[5]

Levy and Newell (2005) propose a neo-Gramscian IPE approach to international environmental politics to extend beyond what they describe as overly state-centric international relations (IR) approaches to better account for the important role of non-state actors – specifically business – in environmental politics and governance. In addressing the role of business in environmental politics, Levy and Newell find that, on the one hand, IR approaches are overly state-centric; on the other, management and corporate political strategy approaches are decontextualized from wider relations of power (Levy and Newell 2005, p.57). Levy and Newell (2005, p.49) present their neo-Gramscian approach as a linking of IR theory at the macro scale and management theory at the micro scale. The neo-Gramscian approach is thus also intended to bridge the two analytical scales.

We propose linking the neo-Gramscian IPE approach with resilience approaches as a further extension again in theoretical analysis of climate crisis in the Earth system. We link Levy and Newell's neo-Gramscian political economy to resilience approaches towards creating a yet more comprehensive perspective. Our intention is to extend beyond a human-social system focus to an integrated social-ecological system framework (i.e. humans in the environment), and with due attention to the role of power and politics in social-ecological systems.[6]

3.1 Theoretical consistencies

Both resilience approaches to social-ecological systems and neo-Gramscian IPE approaches to global environmental governance are particularly amenable to further development. On the one hand, resilience approaches (and complex adaptive systems approaches generally) hold great promise and invite continued development. On the other, Levy and Newell (2005,

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[5] It may be that other approaches to politics and power such as realist international relations theory (e.g. Carr 1939; Morgenthau 1948) can be linked to resilience approaches in the way we link the neo-Gramscian approach. This is not explored in this paper. We see value in Levy and Newell's (2005) explicit attempt to move beyond a state-centric analysis and suggest that a more inclusive conception of who the relevant actors in environmental governance is useful for a conceptual approach that aims to address power in broader social-ecological systems. With reference to climate change at global scale for example, Newell and Paterson (1998) have demonstrated the global climate regime centres not solely on states, but on relationships between states, capital, energy production, and industrial societal reliance on continued carbon-based economic growth.

[6] A sub-literature on governance is growing in the social-ecological systems area (e.g. Young 2005; Galaz *et al.* 2006; Folke *et al.* 2007; Young *et al.* 2008). The governance focus addresses the difficulty of designing human institutions, where *institutions* refers to 'assemblages of rights, rules, decision-making procedures, and programmatic activities that guide or govern human activities' (Young 2008, p.115) with the capacity to deliver effective governance of non-linear social-ecological systems. This is certainly an important challenge. However conflict grounded in differing interests and values that are contradictory, and even irreconcilable, is not wholly accommodated by better design of social-ecological system management frameworks or governance arrangements. With this in mind, our expectation is that exploring linkages between resilience approaches to social-ecological systems and political economy may also prove useful through explicitly acknowledging and accounting for political conflict and contestation.

p.53) note ‘the unfinished nature of Gramsci’s notes and the complexity of the theoretical challenge’ and argue the value of Gramsci’s ideas is not in their completeness, but in ‘the inspiration he has given to many contemporary theorists in their treatment of [international political economy] issues’.

Both perspectives conceptualise non-equilibrium systems and, in the case of resilience approaches, explicitly and purposively so. Resilience approaches to social-ecological systems by definition are geared towards systems characterised by non-linearity, thresholds, with capacity for surprise, and with the potential for multiple stable states (Phelan *et al.* 2010b). For its part, Levy and Newell’s (2005) neo-Gramscian approach to environmental governance also focuses on contingent stability in political economic systems. Levy and Newell (2005, p.50) argue that hegemony is ‘contingent’, with ‘hegemonic stability… rooted in… the projection of a particular set of interests as the general interest’.

Resilience approaches to social-ecological systems focus on whole systems’ states and dynamism, cognizant that system state is a function of (i) changes internally to the system and component subsystems, and (ii) perturbations from outside the system. Scale is thus an important aspect of system analysis. The term *panarchy* (Gunderson and Holling 2002) describes the relationship between systems at differing scales, with smaller systems ‘nested’ within larger systems, and with systems subject to cross-scale interaction.

In contrast, Gramscian analysis centres on interests and actions of actors relative to each other internally to systems under analysis. Cross-scale interaction is at least conceivable in Gramscian analysis, and is emphasised in Levy and Newell’s (2005) application of the neo-Gramscian approach to global environmental governance. Levy and Newell argue (2005, pp.53-5) that whilst Gramsci wrote mostly with reference to national political economies, there is reference in Gramsci’s notes to larger scales (regional and international), and that Gramsci’s key concept of hegemony is applicable in an international context. Levy and Newell (2005, p.55) further argue Gramsci’s value in contemporary understandings of environmental governance lies ‘in the concept of hegemonic formations as complex dynamic systems comprising overlapping and interpenetrating subsystems’. This approach to political economy is evocative of the panarchy concept as applied to social-ecological systems.

The theoretical consistencies between neo-Gramscian approaches to environmental governance and resilience approaches to social-ecological systems suggest at least some potential for linkages. However the two approaches are neither wholly synonymous nor wholly compatible and differ in important ways.

Firstly, resilience approaches as applied to ecological and social-ecological systems are grounded in ecological reality, i.e. they acknowledge the primacy or ‘non-negotiability’ of ecological elements of social-ecological systems such as ecological limits (Meadows and Club of Rome 1972; Meadows *et al.* 2004). This is consistent with Dryzek's (1987) concept of ecological rationality, which involves consideration of social choice mechanisms in various social systems in terms of their consistency with long-term ecological sustainability. Political economy, even when focussed on environmental governance, generally treats ecological rationality as contextual to the main game, i.e. as a backdrop to political economic contestation. Ecological rationality for political economy is thus important, but not the focus.

Secondly, the origin and development of both theoretical approaches are different enough to suggest at least some inconsistencies are likely. Inconsistencies in turn suggest challenges, but perhaps also the possibility of building a conceptual framework[7] with greater understanding of politics in human-dominated social-ecological systems.

3.2 Resilience and hegemony

The relationship between the concept of *resilience* in the context of social-ecological systems, and *hegemony*, a key concept in critical neo-Gramscian international political economy, provides linkage points between complex adaptive systems theory and political economy theory. Here we review briefly both concepts and their contexts, and outline the way we link the two.

The concept of *resilience* has evolved substantially since Holling's (1973) seminal paper and is interpreted in various ways (Folke 2006). Walker et al. (2004) define resilience as 'the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks'. Loss of resilience implies the system state shifting to either an unstable state or an alternative stable state, both of which are unfamiliar.

Gramsci's *hegemony* 'rests on coalitions and compromises that provide a measure of political and material accommodation with other groups, and on ideologies that convey a mutuality of interests' (Levy and Newell 2005, pp.49-50). As noted above, hegemonic stability is dependent on the projection of a 'particular set of interests as the general interest' (Levy and Newell 2005, p.50). Hegemony describes the dominant position of an alliance of actors and groupings within a political economic system.

Gramsci's term for the group of actors in a hegemonic position is an *historical bloc*. An historical bloc 'exercises hegemony through the coercive and bureaucratic authority of the state,

[7] A conceptual framework is neither a model that describes how things work, nor a theory, which explains phenomena. Rather, a conceptual framework helps to think about phenomena, order material and reveal patterns, which can then lead to models and theories (Rapoport 1985, p.256; in Berkes and Folke 1998, p.15).

dominance in the economic realm, and the consensual legitimacy of civil society' (Levy and Newell 2005, p.50). The term refers to both

> 'the alliances among various social groupings and also to the specific alignment of material, organisational, and discursive formations that stabilise and reproduce relations of power and meaning. These two meanings of "historical bloc" are closely related, for the ability to mobilise an effective alliance requires not just economic side-payments but also discursive frameworks that actively constitute perceptions of interests' (Levy and Newell 2005, p.50).

We extend the given interpretation of hegemony and suggest that, in the anthropocene, an historical bloc may be dominant to the extent that it strongly influences the political economic system in which it is contained *as well as* the larger social-ecological system in which the political economic system is nested.

Our focus is the extent to which anthropogenic climate change is an aspect of hegemonic dominance of the state of the Earth system, undermining the familiar stability of the Earth system, and in turn threatening the resilience of human societies and cultures. Anthropogenic climate change is a feature of the long-standing societal commitment to carbon-based economic growth. Over time, the increasing centrality of fossil fuels to economic expansion, combined with an increasing and ultimately overwhelming commitment to economic growth has also led to what can be termed a fossil fuel historical bloc, comprising fossil fuel corporations and industry representative organisations, governments dependent on economic growth for their societal legitimacy, and others (see Newell and Paterson 1998). In neo-Gramscian terms, the fossil fuel historical bloc is structurally powerful (i.e. fossil fuels are of central importance to continued economic growth) and resistant to its position being weakened, for example through an ecologically rational shift to a de-carbonised economy. In systems terms this could be described as perverse resilience: resilience in a subsystem of human-social systems that threatens the familiar Earth system stability on which human society depends.

Levy and Newell's (2005) approach emphasises contingent stability in political economic systems, where current stability in the system benefits the historical bloc in a hegemonic position, to the detriment of others. From the perspective of those excluded from the historical bloc and assuming a counter-hegemonic position, the current stability in the system is oppressive and something to be actively contested. Levy and Newell (2005, pp.49 & 64) note one of the benefits of their theoretical approach is the potential to identify (limited) opportunities available to comparatively poorly resourced actors to achieve – through 'sophisticated analysis and strategy, good timing, and some luck' (p.64) – political economic change counter to the hegemonic interests of the historical bloc. We suggest extending the analysis from political economic systems to social-ecological systems may also be useful, generating a new integrated understanding of the relationship between hegemony and Earth system resilience, in support of achieving sustainability.

Attention to the broader social-ecological system beyond the perspective from political economy highlights the ecological implications of hegemonism. There is no guarantee that hegemonic dominance of human-social elements of a social-ecological system is consistent with the ongoing stability of the wider social-ecological system. Indeed, climate change – and other global sustainability crises – suggest the opposite is more likely. This is perhaps unsurprising. Social and environmental injustice originating in imbalances in power frequently go hand-in-hand (Pettit 2004; Hayward 2006; Jones 2008, pp.47-48).

A hegemonic system state in neo-Gramscian terms implies a systemic absence of justice and equity, and therefore a compelling rationale for counter-hegemonic contestation. Including attention to the ecological dimension of social-ecological systems raises questions about the relationship between hegemony and the social-ecological system in which it is founded. We suggest hegemonies that reproduce values and practices inconsistent with system sustainability can be highly undermining of both the socio-economic resilience of groups outside the historical bloc and of social-ecological system resilience overall (Pettit 2004; Hayward 2006). With reference to climate change, the fossil fuel historical bloc, nourished by ideas such as the primacy of economic growth (see Daly 1982) and the substitutability of natural capital (see Hawken *et al.* 1999), is negatively impacting the familiar stability of the Earth system.

This in turn raises important questions about the impact of increasingly threatened Earth system resilience on the contingent hegemonic stability enjoyed by the fossil fuel historical bloc. Increasing the precariousness of overall Earth system resilience is contrary and detrimental to the broader societal interest. As such, over time the historical bloc's discursive efforts aimed at securing broad societal acceptance of its specific interests as the societal interest are also liable to be weakened.

The comparative position of the historical bloc may also be undermined materially through reduced Earth system stability. Climate change implies greater Earth system unpredictability. The potential for hegemony over the state of a social-ecological system may also be more limited than potential for hegemonic dominance in a political economic system. Whilst the notion of the 'anthropocene' points to humans as the dominant driver of change in the Earth system, this is not the same as humans having (sophisticated, nuanced, directional) control over the course of Earth system change.

3.3 Picturing climate politics in the Earth system

Two figures have been developed that together help to describe a way of linking hegemony and resilience in the context of climate change in the Earth system. For both figures we have drawn on resilience approaches that make use of a metaphorical ball moving around in basins or across other features of a stability landscape (e.g. Scheffer *et al.* 2002 pp.203-204; Walker *et al.* 2004) to represent the state of a social-ecological system, its resilience and its potential for change.

Figure 1 shows in abstract and metaphorical form near *current* hegemonic influence on the state of the Earth system. Figure 1 represents primarily two dimensions showing a system state ball (hereafter ball), in cross-section and in close proximity to a climate threshold, to reveal how hegemony in the system drives the ball across a system state surface (hereafter surface).[8] The companion Figure 2 (depicting three dimensions), also abstract, focuses on hegemony's *historical* influence on the state of a social ecological system. Figure 2 shows historical hegemonic impacts in the form of changes over time in the surface's features, and in turn the effect of changes in the surface's features on the location, movement and potential for movement of the ball. The state of the Earth system is indicated by the ball's location on the surface, i.e. in the relationship between the ball and the surface. Hegemony therefore influences and constrains the ball's location, movement and potential for movement across the surface in two ways.

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FIGURE 1 ABOUT HERE

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Figure 1 comprises three panels (**a**, **b** and **c**), which together represent the state of political contestation in the Earth system at a sequence of time points, beginning in the present: at circa 2010. Each panel shows a cross-section of a ball, revealing the way the state of political contestation drives the ball across the surface. Within the ball are smaller balls, each representing political economic actors and/or groupings. Figure 1 highlights the first way the ball may change location across the surface, i.e. through being driven across the surface.

3.3.1 a Inside the system state ball now, circa 2010.

In panel **a**, the *fossil fuel historical bloc* ball is the largest internal ball, reflecting the fossil fuel historical bloc's dominance of the Earth system state. The fossil fuel historical bloc comprises

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8 Resilience approaches use the term 'stability landscape' (e.g. Walker *et al.* 2004). In the interests of simplicity and clarity, we use 'system state surface' to refer to a surface of infinite area that is wholly flat aside from the features necessary for articulating the resilience-hegemony conceptual link.

formal and informal networks of actors and groupings with perceived and actual interests reliant on continued societal need for carbon-dependent economic growth. Example actors and groupings constituting the fossil fuel historical bloc include the oil, coal and energy-intensive sectors, and governments relying on continued carbon-dependent economic growth to maintain their societal legitimacy. The fossil fuel historical bloc ball is shown spinning (direction indicated by the large arrow) within the ball. By virtue of its dominance, the fossil fuel historical bloc ball sets the direction for the path taken by the larger ball (from right to left, indicated by the large open arrow), and drives the ball's movement across the surface.

Counter-hegemonic sustainability forces are represented as the smaller counter-hegemonic sustainability forces ball. Counter-hegemonic sustainability forces coalesce around shared perceived and actual interests that are in opposition to continued human social reliance on carbon-dependent economic growth, i.e. in opposition to those interests that draw together the actors and groupings comprising the fossil fuel historical bloc. Counter-hegemonic sustainability forces comprise example actors and groupings such as civil society groups campaigning for emissions reductions and governments of small island states clearly vulnerable to rising sea levels. The counter-hegemonic sustainability forces ball is separate from the fossil fuel historical bloc ball, also spinning (direction indicated by the arrow), but in a different direction. Counter-hegemonic sustainability forces are attempting (unsuccessfully in panel a) to drive the system state in a direction other than that of the historical bloc.

In panel **a** various *unaffiliated/disengaged actors and groupings* balls are also visible, spinning (directions indicated by arrows) generally in a direction that is consistent with that set by the fossil fuel historical bloc (i.e. the status quo). Examples of unaffiliated/disengaged actors and groupings are individuals and communities who accept the fossil fuel historical bloc's discursive claim that carbon-dependent economic growth is in the general interest, but are not themselves part of the fossil fuel historical bloc, i.e. without a strong vested interest in continued carbon-based economic growth. Consistent with the hegemonic position of the fossil fuel historical bloc, unaffiliated/disengaged actors and groupings accept the fossil fuel historical bloc's interests as the general interest, and therefore overlapping with their own, consistent with the fossil fuel historical bloc's hegemonic dominance of the system state. Unaffiliated/disengaged actors and groupings are of little consequence for the path taken by the ball.

The state of the Earth system is described by the location of the ball on the surface. Panel **a** shows the ball located within the stability domain we label Dfs (Domain: familiar; stable), i.e. the Earth system state domain that is familiar (to humans and our civilisations) and stable. In panel a, the ball's path from right to left across the surface is indicated by the large open arrow. The fossil fuel historical bloc's effort to maintain hegemonic dominance of the Earth system state is pushing the ball across Dfs, towards a climate change threshold and beyond to an alternative stability domain, representing an alternative system state. Dus (Domain: unfamiliar, stable), is an unfamiliar (to humans and our civilisations) domain, and one that is also stable. An example would be the Earth system with a higher average global mean temperature and an ice-free state.

3.3.2 b Inside the near future system state ball: a shift in contingent hegemonic stability

In panel **b** the fossil fuel historical bloc's dominance of the system state continues. However, one feature of contingent hegemony is continually negotiated alliances between actors and groupings. Panel **b** shows an actor/grouping no longer perceiving its interests as consistent with those of the fossil fuel historical bloc. The actor/grouping is shown withdrawing from the fossil fuel historical bloc, leading to a weakening in the fossil fuel historical bloc*'s* hegemonic dominance of the system state, reflected in the reduced size of the fossil fuel historical bloc ball. Also shown in panel **b** is an actor/grouping beginning to perceive its interests as consistent with those of counter-hegemonic sustainability forces. The ball representing this actor/grouping is shown joining with the counter-hegemonic sustainability forces, leading to a strengthening of the counter-hegemonic sustainability forces, reflected in the increased size of the ball representing counter-hegemonic sustainability forces. Nevertheless, the fossil fuel historical bloc remains the dominant influence on the system state. The large open arrow gives a sense of the fossil fuel historical bloc's continued capacity to drive the ball's path across the surface.

In panel **b** the fossil fuel historical bloc has continued to drive the system state ball from right to left. The ball has been driven outside of Dfs, up and over the climate threshold and into the alternative stable state Dus. In practice, the anthropogenic shift in the Earth system from one stable state to another entails crossing a series of climate thresholds of varying significance. Examples could include globally significant Earth system tipping points such as the loss of the Greenland ice sheet; locking into a single mode of El Niño–Southern Oscillation, and disruption of the Indian summer monsoon and the Atlantic thermohaline circulation (Lenton *et al.* 2008). In practice, there are many Earth system thresholds, at multiple scales. System thresholds are not always discernible, sometimes even well after they have been crossed (Keller *et al.* 2008). For clarity of representation in Figure 1 we combine all climate thresholds separating the two stable states into a single threshold. As with panel **a**, unaffiliated/disengaged actors and groupings, which are of little consequence to the path taken by the system state ball, are also shown.

3.3.3 c Inside the system state ball a little later: turning around the system state

Panel **c** shows substantial change in the comparative position of political economic actors/groupings, and this is reflected in the ball's direction of travel. In panel **c** previously counter-hegemonic sustainability forces have successfully undermined the fossil fuel historical bloc*'s* hegemonic grip on the state of the Earth system. In the course of doing so, they have been joined by additional actors/groupings, such that a new sustainability hegemony has come to dominate the system state. The newly-labelled *sustainability historical bloc* ball is now the largest, reflecting its newly attained dominance of the system state. The sustainability historical bloc's dominance of the system state is driving the ball in a new direction: from left to right, i.e. across Dus (Domain: unfamiliar; stable), with the intention of leaving Dus, crossing the climate threshold and returning to Dfs (Domain: familiar; stable). In practice, a system state's return journey to a previous stability domain may be easy, difficult or impossible. System hysteresis[9] suggests a return journey from Dus to Dfs may be more difficult (i.e. the ball travels a different path across the surface) than the outward journey. With reference to the Earth system and climate change, a return to the familiar stable state of the Earth system after climate change may not be possible within a human-scale timeframe, if ever (Crowley and Hyde 2008).

In panel **c** actors/groupings that once constituted the fossil fuel historical bloc have continued to perceive their interests as inconsistent with those of the previous hegemony, and have left the fossil fuel historical bloc. The remaining fossil fuel actors/groupings now comprise a counter-hegemonic force, and their reduced influence on the system state is reflected in the reduced size of the newly-labelled *counter-hegemonic fossil fuel forces* ball. As with panels **a** and **b**, unaffiliated/disengaged actors and groupings, which are of little consequence to the path taken by the system state ball, are also shown.

3.4 Expanding the picture of climate politics in the Earth system

Figure 2 illustrates the temporal evolution of the Earth system and expands it into a three-dimensional view. Figure 2 depicts the history of anthropogenic climate change for roughly the ~160-year period preceding that described in Figure 1. It comprises a sequence of three panels (**a**, **b** and **c**) that in an abstract and metaphorical form show the *historical* influence of hegemony in the Earth system over time on the state of the Earth system, culminating at circa 2010: **a** pre-anthropogenic climate change (i.e. circa 1850); **b** early anthropogenic climate change (i.e. circa 1950); and **c** later anthropogenic climate change (i.e. circa 2010). Changes are in the first instance attributable to anthropogenic climate change, in turn an outcome of the fossil fuel historical bloc*'s* long-standing hegemonic grip on the Earth system. Figure 2 accompanies the earlier Figure 1 where the emphasis was on the internal workings of the ball. In Figure 2 our emphasis shifts to: (i) the location of the ball on the surface; and (ii) changes over time in the surface's features that influence and constrain the ball's location. Figure 2 highlights the second way the ball may change location on the surface, i.e. through driving changes in the surface's features.

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[9] System hysteresis is an important feature of systems with alternative stable states. When a system state passes a threshold and switches from one stable state to another, a simple restitution of conditions immediately preceding the switch may be insufficient for a return to the previous state. Hysteresis implies that after perturbation, the system returns to its original state via a different path. Conditions from an earlier point may need to be reinstated before the system can switch back to its previous state (Scheffer *et al.* 2001, p.591). See also Budyko (1969).

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FIGURE 2 ABOUT HERE

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Stability domains in the surface, expressed as depressions or 'cups', indicate possible stable states for the system: once the ball is in a cup, and whilst the cup persists, the ball will tend to stay within that domain. Using a surface is helpful for expressing the potential for complex adaptive systems to have multiple stable states, represented as multiple cups in the surface. Theoretical surfaces are infinite and may have other features also. Sloped and peaked areas of the surface, for example, indicate unstable system states, i.e. the ball will not tend to stay within such domains. For clarity in Figure 2, the area of the surface is limited and we refer to and depict only three features. These are the two 'cups' located in a third Earth system stability domain. Of these domains (D), one is familiar (f) while the other two are unfamiliar (u). Both 'cups' are stable (s). We label the whole of the surface other than the two stability domains on which we focus as Duu: a possible system state domain (i.e. location for the ball) that is both unfamiliar and unstable. Dotted lines delineate the threshold between domains. In each panel, the state of the Earth system is represented by the location of the ball on the surface. Change in the system state is represented by the ball rolling across the surface. Potential for change in the system state is represented in part by the surface's features. Across the three panels, change in potential for system state change is reflected in changes in the plane's features.

3.4.1 a Before anthropogenic climate change (i.e. circa 1850)

Panel **a** shows the surface with one key feature: the large stability domain we label Dfs, i.e. the Earth system state domain that is familiar (to humans and our civilisations) and stable. The ball is deep in the cup. Continuing familiar Earth system stability is represented by the ball remaining within the bounds of the cup. Panel **a** reflects the Earth system state before the onset of anthropogenic climate change, i.e. at the onset of the Industrial Revolution.

3.4.2 b Early anthropogenic climate change (i.e. circa 1950)

Panel **b** shows the Earth system state at an early stage in climate change, e.g. just after the Second World War. Cumulative greenhouse gas emissions into the Earth system has led to the creation of a large new and alternative stability domain in the surface, to the left of Dfs. We label the new domain Dus: it is an unfamiliar domain, and one that is also stable. The creation of Dus reflects the anthropogenic increase in atmospheric greenhouse gas concentrations that constitutes climate change in the Earth system. Dus unfamiliarity means it entails considerable uncertainty for humans.

Increased atmospheric greenhouse gas emissions also constrain the potential for the Earth system to remain in its current stable state. This is represented as a Dfs that has decreased in size: it is now narrower and shallower. The shrunken Dfs represents reduced Earth system resilience. A decreasing Dfs leaves the ball closer to the edge of the cup. Whilst the ball remains in Dfs (and therefore the Earth system remains stable), its proximity to the edge of the cup represents reduced system resilience. In comparison to the situation represented in panel **a**, both a smaller change in the features of the surface and a smaller shift in the ball's location would move the ball outside of stability domain Dfs.

3.4.3 c Later anthropogenic climate change (i.e. circa 2010)

Panel **c** shows the Earth system in a later stage of climate change, i.e. the present day. Atmospheric greenhouse gas concentrations continue to increase, making the Earth system state's familiar stability even more precarious. This is depicted by Dfs continuing to shrink, leading to the ball being in even closer proximity to the edge of the Dfs. Dus has enlarged considerably, to the extent that a potential passage for the ball across a climate threshold from Dfs to Dus is created in the surface. As noted for Figure 1, in practice, the anthropogenically-driven shift in the Earth system from one stable state to another entails crossing a series of thresholds of varying size and significance. For clarity of representation we have collapsed all climate thresholds separating the two stable states into a single threshold.

3.5 The evolving relationship between hegemony and the Earth system: Combining concepts and figures

The system state may change (i.e. the ball move across the surface) in three ways, with hegemony implicated in two. Firstly, hegemony is implicated as an immediate endogenous perturbation that influences the system state, as depicted in Figure 1. Change of this kind in the system state is reflected in the ball being driven in particular directions across the surface. Such movement may or may not be in alignment with the surface's features. That is, whilst the ball will tend to roll down slopes in the surface, a sufficiently strong endogenous perturbation can push the ball uphill, e.g. up and over a threshold.

Hegemonic influence on the system state comprises material, organisational and discursive elements. These include current continuing and even increasing investment in fossil fuel and energy intensive infrastructure and resultant CO_2e emissions (i.e. material elements), contemporary formal and informal networks of actors and groupings with substantial stakes in continued economic reliance on fossil fuels (e.g. see Pearse 2007, 2009) (i.e. organisational elements) and a continually reproducing societal commitment to carbon-dependent economic growth, even as the implications of continued emissions are clear (i.e. discursive elements). Movement of the ball across the surface in response to more immediate perturbations represent changes in the values of system variables (Beisner *et al.* 2003). The Earth system is understood as a social-ecological system, complex and adaptive, and comprising ecological as well as human-social elements. Human influences are not the sole drivers of change in the Earth system, but are significant and a concern of this paper.

The second way in which the fossil fuel bloc's historical hegemony is implicated in changes in the state of the Earth system is in accumulated changes in the surface's features. The surface is dynamic. Whilst the creation and shaping of features in the surface is not wholly a result of hegemony in the political economic subsystem, human influences are significant.

Hegemony comprises closely intertwined material, organisational and discursive elements (Levy and Scully 2007). In our example, hegemonic influence reflected in the features of the surface comprises (i) anthropogenic atmospheric CO_2e concentrations accumulated over time through increasing industrialisation since 1850 (i.e. material elements), (ii) the alliances developed and maintained between particular actors and groupings (e.g. networks comprising the fossil fuel sector, governments dependent on carbon-dependent economic growth for their continued social legitimacy) that since industrialisation have ensured the political primacy of carbon-dependent economic growth (i.e. organisational elements) and (iii) the increasingly intensive and rigid commitment to carbon-dependent economic growth (i.e. discursive elements). Changes in the surface's features typically occur gradually. Features in the surface have been likened to represent changes in the parameters of the system drivers (Beisner *et al.* 2003).

Lastly, understood as a complex adaptive system, the Earth system state also changes continuously and unpredictably in response to endogenous perturbations in the system, e.g. volcanic eruptions substantial enough to influence the climate system. Endogenous perturbations are a feature of complex adaptive systems and the ball is therefore never static. Complex adaptive systems' movements to equilibrium points are continuously buffeted off course. Even when the ball is located in a stability domain (represented by a cup in the plane) and tending towards the local equilibrium point (i.e. towards the bottom of the cup), the system will not achieve equilibrium. We note this but do not consider it in this analysis.[10] The Earth system, conceptualised as a complex adaptive system, has always been inherently unpredictable. However, its state has been relatively stable for the course of human history, i.e. the ball has remained within the one cup. The focus in this paper is the manner in which anthropogenic climate change

[10] Nor do we address possible exogenous perturbations, e.g. asteroid impacts, which lie outside the paper's focus on linking resilience and hegemony in the context of climate change.

is moving the state of the Earth system from a state of relative predictability to a state of unpredictability, and the implications of that shift.

In summary, the fossil fuel bloc's hegemonic grip on the state of the Earth system over time (evolution from ~1850 to ~2010 depicted in Figure 2) has created a new, unfamiliar and stable potential state for the Earth system, together with a pathway to that state. Additionally, the effect of the fossil fuel bloc's current hegemony in the Earth system (Figure 1 a) is to drive the system state from its current familiar state towards the new and unfamiliar state (Figure 1 b).

4. Justice in the anthropocene: Undermining perverse resilience

This section applies the linked resilience and neo-Gramscian conceptual approach towards understanding and undermining perverse resilience in social-ecological systems. An explicitly political approach to systemic change would be uncontroversial in the political economy arena, but is more unusual in the context of resilience approaches to social-ecological systems. The section concludes with an application of the conceptual approach outlined here to a climate change case study.

There are important political economic challenges in the anthropocene (Crutzen and Stoermer 2000; Crutzen 2002), where (inherently political) anthropogenic dynamism is the dominant driver of change in the Earth system. The familiar stability of the Earth system as the foundation of human societies is in play. Life as we've known it is in question: the struggle for sustainability is therefore a high stakes game.

Firstly, social-ecological systems entail limits to political compromise that do not feature in political economic contexts and are not amenable to accommodation or coercion. Lovelock (2006; 2007) can be interpreted as suggesting that Gaia is forgiving, but does not negotiate. Actors in the social-ecological Earth system have been negotiating responses to climate change and other anthropogenic crises amongst themselves for several decades, for example through UNFCCC processes (United Nations 1992). All the while, Earth system limits remain unmoved (Catton Jr 1980).

Secondly, features of the Earth system are inherently challenging, and particularly so as we shift the Earth system to a comparatively less stable state. Actors' interests, and perceptions of their interests, may change over time, in response to actual and perceived changes in the social-ecological system. Actors' capacities to define (and even comprehend) their strategic, long-term interests in a comparative sense (i.e. in contrast to others' interests), and with the goal of achieving or maintaining a hegemonic political economic position, is highly uncertain and, perhaps ultimately, not feasible with any precision in this context. This is because: (i) the key temporal and spatial scales are extremely challenging; and (ii) the Earth system is a complex system characterised by non-linearity with the capacity for surprise (Phelan *et al.* 2009). As noted earlier, significant Earth system thresholds may not be identifiable, even long after they have been crossed (Keller and McInerney 2008; Keller *et al.* 2008). Relationships between the Earth system, the global economy and subsystems are continually evolving, and therefore understanding of them is necessarily incomplete (Phelan *et al.* 2010b).

Maintaining hegemony in a non-linear Earth system is complicated. Undesirable hegemony of values and practices that undermine the resilience of the Earth system will over time compromise the familiar stability of the Earth system, on which humans and our societies depend. In the absence of ecologically effective mitigation, the loss of familiar Earth system stability will continue, manifested as a succession of globally significant and smaller changes as thresholds are crossed (Lenton *et al.* 2008). Some changes are effectively permanent in human terms (Solomon *et al.* 2009). Anticipated changes are profound, and thus challenging even for those in the historical bloc and more privileged political economic locations more generally. Such changes will impact human populations unequally but comprehensively. Whilst some societal groups are more vulnerable than others, all will be impacted. Uncertainty around impacts will remain high and increase as the state of the Earth system continues to change, reducing predictability.

Even though maintaining a hegemonic grip on the Earth system under such conditions is complicated, undermining perverse resilience of the fossil fuel historical bloc under the same conditions also poses a substantial challenge. Nevertheless, under such conditions, opportunities for undermining the hegemony of the fossil fuel historical bloc may arise. As noted earlier, Levy and Newell (2005, p.64) suggest a neo-Gramscian approach to global environmental governance suggests (limited) opportunities for challenging hegemony. And as noted above, climate change threatens the material basis for the historical bloc's dominance as well as discursive efforts to present its specific interests as the broader societal interest. Climate change therefore threatens the contingent hegemonic stability aligned with the historical bloc's dominant political economic position.

4.1 'We are all behind enemy lines': Climate crisis in the Earth system

In this section we use climate change mitigation as a case study to contrast the whole-of-system resilience focus and the conflict-within-the-system critical political economy focus. Our aim is to demonstrate a pertinent example of the value of linking critical neo-Gramscian approaches to political economy with resilience approaches to social-ecological systems. We begin with two armed conflict metaphors used in the climate change context, useful because each reflects one of the focuses above. The first, a war metaphor, is a commonly applied call to arms in defence against an external threat. The second, the notion that we are all behind enemy lines, refers to internal socio-political struggle and has anarchist roots. Metaphors are critical to achieving socio-political change (Cohen 2010). We then suggest setting aside both military metaphors noted above in favour of other sources of inspiration that may prove more appropriate. As such this case study is limited to exploration of hegemony's discursive element.

The war metaphor (e.g. Leggett 2007), where war implies a unified, defensive societal response to an impending threat of invasion, has been used to describe the kind of responses climate change mitigation requires (Cohen 2010). It is a powerful metaphor, and useful to the extent it intimates the magnitude of the effort required to effectively, equitably and justly mitigate climate change. However, the metaphor has limitations. Firstly, it frames climate change as an external threat.[11] Secondly, prosecuting wars (at least those armed conflicts involving states) is typically a government-directed exercise, dependent on leadership by governments. Governments to date have been exceedingly ineffective across the board in responding to climate change. Despite decades of policy discussion, design and implementation, global CO_2e emissions rates and atmospheric concentrations continue to rise well beyond (rather than reduce to within) biogeophysical limits: '…the acceleration of both CO_2 emissions and atmospheric accumulation [in the period 2000-2007] are unprecedented and most astonishing during a decade of intense international developments to address climate change' (Global Carbon Project 2008). This is not surprising, given states' reliance on maintaining economic growth (Paterson 2001), and in turn the reliance of economic growth on burning fossil fuels. To greater and lesser extents particular elements of governments, such as industry ministries, as well as governments overall are key parties to the fossil fuel historical bloc. As such there are limitations to the prospects for governments to initiate radical shifts in position on climate change towards ecologically effective mitigation policy and action.[12] We suggest the war metaphor shares the whole-of-system perspective of resilience approaches.

The anarchist assertion 'we are all behind enemy lines' shares with the war metaphor a reference to armed conflict between two groups. It is both evocative and perceptive in describing the challenge to effectively, equitably and justly mitigate climate change. It's also helpful towards exploring the possibilities for linking resilience and political economy approaches. It differs in that it reflects the conflict-within-the-system focus of political economy theory.

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[11] We have experimented with the war metaphor to render it fit for purpose by toying with notions of 'traitors' and 'war profiteers' as metaphors for the historical bloc internal to our societies currently with a hegemonic grip on the Earth system. However neither term resonates with the sense of overwhelming political economic dominance inherent in the concept of hegemony. Further neither addresses the unhelpful notion of climate change as an external threat.

[12] This is particularly so in a global economy transformed by corporate globalisation in which the vagaries of massive private financial flows, e.g. the threat of capital flight, can act to curtail governments' policy autonomy (Dryzek 1996).

Climate change mitigation and adaptation, consistent with important principles of equity and fairness, have been near-universally adopted as important shared goals by national governments, as expressed for example in the UNFCCC (United Nations 1992). Yet effectively mitigating climate change is not a goal shared universally through societies. Societal commitment to economic growth and its carbon basis since the Industrial Revolution underpins the substantial depth and breadth of overlapping political economic interests that constitute the fossil fuel historical bloc. The fossil fuel historical bloc comprises alliances of powerful actors ranged against ecologically effective, equitable and just climate change mitigation. Opposition to effective climate change mitigation can appear to be more or less reasonable. The Asia–Pacific Partnership on Clean Development and Climate is one apparently legitimate but voluntarist initiative that in effect undermines the existing, binding Kyoto Protocol (McGee and Taplin 2006).

Apparently neutral contributions to environmental discourses also play a role. Of 141 English language books denying the seriousness of environmental problems (including climate change) published between 1975 and 2002 (most of which were published in the US since 1992), more that 92% are linked to conservative think tanks; furthermore, of conservative think tanks active on environmental issues, 90% espouse environmental scepticism (Jacques *et al.* 2008). Overtly partisan and highly destructive corporate PR campaigns (Gelbspan 1998) also reflect the historic bloc's defence of its hegemonic position (for a detailed expose of the fossil fuel lobby's strategic approach to climate policy-making in Australia see Pearse 2007; 2009). Attacks on the legitimacy of the Intergovernmental Panel on Climate Change in the lead-up to the December 2009 climate negotiations in Copenhagen (COP 15) are a case in point (e.g. Henderson 2010; for analysis see Pearce 2010).

However the fossil fuel historical bloc's hegemonic dominance is not total and is contested by counter-hegemonic forces with overlapping interests. Counter-hegemonic groupings, actors who support ecologically effective and just mitigation hold varying views of what constitutes: (i) the specifics of a desirable outcome; and (ii) an appropriate process towards achieving that outcome. Both the power and normative dimensions of climate change demand achieving collective agreement – and then action – on ecologically effective mitigation: an extraordinary challenge. Such agreement is what elements within the fossil fuel historical bloc have actively undermined to greater and lesser extents. This results in a long-standing period during which, while information and analysis about the threat climate change presents is more than sufficient and increasing, climate change remains unmitigated. Climate change is no longer helpfully dealt with *primarily* as a science question (e.g. IPCC 2007a), a technology question or even an economics question (e.g. Stern 2006; Garnaut 2008). Achieving ecologically effective mitigation in the Earth system is a socio-political challenge. Rather than adopting metaphors evocative of armed conflict, we suggest achieving climate change mitigation is most usefully framed as a justice issue, one where climate justice (Pettit 2004; Hayward 2006) provides an appropriate societal process and goal. A climate justice perspective recognises climate change is due to globally unequal exploitation of fossil fuels historically and currently, and that responsibility for mitigating climate change should be allocated accordingly (FOE Australia 2006; Gupta 2007).

Earlier and continuing social movements that entailed radical change (see Powers *et al.* 1997) provide helpful models and metaphors for achieving the social change necessary for effective, equitable and just climate change mitigation. Anti-slavery, universal suffrage, civil rights, peace, anti-apartheid, independence and indigenous land rights campaigns are all examples of grand justice movements either played out at an international scale or with international ramifications (see Zunes *et al.* 1999). In recent years, the global justice movement (sometimes misnamed the 'anti-globalisation' movement) has provided an example of global-scale movement building that accommodates multiple specific interests and perspectives. These include perspectives from both North and South, as well as sectorally varied interests, including environmental rights, labour rights and others (Klein 2002; Solnit 2004).

Adopting a climate justice perspective, climate change is understood as a globally coherent environmental injustice originating in the global economy, a subsystem of the Earth system. 'De-carbonising the economy', 'deep cuts in emissions' and similarly apparently neutral phrases mean, in complex adaptive systems terms, changes to the economy in favour of maintaining the Earth system in its familiar (to humans), stable state. Recalling the sustainability paradox however, seeking and achieving conservation of familiar stability in the Earth system, and therefore the viability of human-social systems internal to the Earth system, depends on radical change in human societies.

Achieving radical change is simultaneously a precondition and an outcome of undermining the perverse resilience of the fossil fuel historical bloc. This is a scenario in which various actors' actual and perceived interests and values are – and will likely remain – in conflict and irreconcilable. It is a scenario in which change implies substantial societal upheaval consistent with earlier successful movements to undermine hegemony. The fossil fuel historical bloc currently defends its hegemonic position effectively, even viciously, and it would be prudent to expect that to continue. Mindful of the course of the great justice struggles, we suggest the notion that we might somehow effect climate change mitigation without significant and widespread societal conflict appears fanciful.

To illustrate, we consider one key, emblematic feature of the process of social change in human social systems: civil disobedience (Roy 2004). Surmounting the profound political economic challenge that climate change presents, i.e. challenging and undermining the historical bloc with a powerful hegemonic grip on the state of the Earth system will surely include widespread and sustained civil disobedience. Non-violent direct action has been a feature of climate justice campaigns for many years already, if perhaps not as prominently as in other environmental campaigns (Gough and Shackley 2001; Hall and Taplin 2007). Yet as with anti-slavery and other justice campaigns, the struggle for climate justice is still to be won. Non-violent direct action will continue to feature.

Our argument is not that civil disobedience is sufficient to successfully undermine the fossil fuel historical bloc, only that it is one likely necessary element of effecting the profound political change on the scale necessary for maintaining the familiar stability of the Earth system. Furthermore, it is an emblematic aspect of societal conflict and change, which is not conceptualised with precision by resilience approaches to social-ecological systems.

Applying the conceptual approach linking resilience approaches with critical political economy to climate change does two things. Firstly, it recognises the scale of the threat climate change presents human societies. Secondly, it accurately identifies the anthropogenic cause of climate change not simply as excessive atmospheric greenhouse gas concentrations, but as the fossil fuel historical bloc's current and historical hegemonic grip on the state of the Earth system. In combination with resilience approaches, the critical political economy perspective helpfully brings to focus the desirability and necessity for radical social change in order to maintain the familiar stability of the Earth system on which human societies depend. Further, the approach provides a sense of the scale and character of the socio-political change necessary for mitigation. Armed conflict metaphors have been applied to climate change, and in some respects are useful. Climate justice provides a better metaphor, and one that shows greater affinity with our conceptual approach. In short, achieving ecologically effective and just climate change mitigation, and therefore maintaining the familiar, stable state of the Earth system, is dependent on effectively undermining the perverse resilience of the fossil fuel historical bloc.

5. Conclusion: Political change in social-ecological systems

Resilience approaches are helpful in making sense of social-ecological systems and are typically directed, if generally uncritically, towards sustainability goals. Linking critical political economy to resilience approaches is useful for better explaining political dynamism in social-ecological systems, why desired and/or agreed sustainability goals are yet to be achieved, and what their achievement might require. This is important with reference to understanding the social and political causes of – and responses to – climate change: both climate change and its mitigation are anthropogenic and therefore grounded in the human-social elements of the Earth system.

The sustainability paradox is that to retain familiar Earth system stability depends on radical change in the human-social elements of the Earth system social-ecological system. Effective, equitable and just climate change mitigation implies profound societal upheaval: certainly the growth and ultimate success of earlier grand justice movements also entailed substantial societal conflict. The fossil fuel historical bloc sees its core interests as wholly wrapped up in continued societal fossil fuel dependency. On this basis it has mobilised skilfully and until now overwhelmingly to defend its self-defined interests which have been threatened by the movement towards mitigation of anthropogenic climate change. This includes characterising its specific interests as the broader societal interest; this is perhaps unsurprising, but certainly inconsistent with maintenance of the Earth system in its familiar, stable state. Against that backdrop, achieving the necessary and profound change to ensure climate justice without significant and widespread societal conflict is extremely unlikely. Achieving effective and just climate change mitigation will, for example, likely entail continued and amplified civil disobedience.

Resilience approaches are yet to grasp with precision or sophistication conflict within human-social elements of social-ecological systems. Two key limitations of current resilience approaches are an uncritical and non-transparent engagement with norms and values, and a bloodless treatment of power in human-social systems. On both counts, neo-Gramscian international political economy approaches to global environmental governance may helpfully augment resilience approaches to political dynamism in social-ecological systems. Critical political economy theory engages explicitly with societal conflict arising from differing political economic interests. Both the resilience and neo-Gramscian approaches are particularly open to further development, and we suggest that combining the two facilitates increased understanding of climate crisis as a globally coherent anthropogenic – and therefore political –phenomenon of the Earth system.

Systemic crises in social-ecological systems are challenges with particular qualities. Climate change in the Earth system is a key example. The phenomenon is mediated by climate science, which is vast, difficult, and requires training and committed engagement to grasp. The phenomenon's temporal and spatial scales are challenging for humans and our societies to engage with. The hegemonic forces arranged against effective, equitable and just mitigation responses are the most difficult challenge of all. Resilience approaches explain well the manner in which climate change threatens the viability of human societies dependent on maintaining the familiar stability of the Earth system. Critical political economy appropriately sets out the threat climate change mitigation presents to the fossil fuel historical bloc's hegemonic grip on human societies. In combination, the two approaches articulate the desirability and need for fundamental change in human societies, as well as the challenge in achieving the ecologically necessary change.

Climate change is a 'diabolical problem' (Garnaut 2008, p.xviii). Mitigating climate change effectively, equitably and justly means undermining the current fossil fuel historical bloc. Undesirable hegemony over human-social system elements is consistent with the notion of perverse resilience, which undermines the resilience of the larger social-ecological system, upon which humans and our societies are ultimately dependent. Yet even as resilience may or may not be perverse, hegemony may or may not be unjust or unsustainable. We propose that hegemony consistent with ecological sustainability values may support the resilience of the larger social-ecological Earth system in which the human-social system is constituted. In place of the fossil fuel historical bloc we imagine a new hegemony with interests explicitly aligned (and recognised as such) with ecologically effective and just maintenance of familiar Earth system stability. Although the relationship between resilience and hegemony requires further investigation, we suggest that a just sustainability hegemony can support a resilient Earth system.

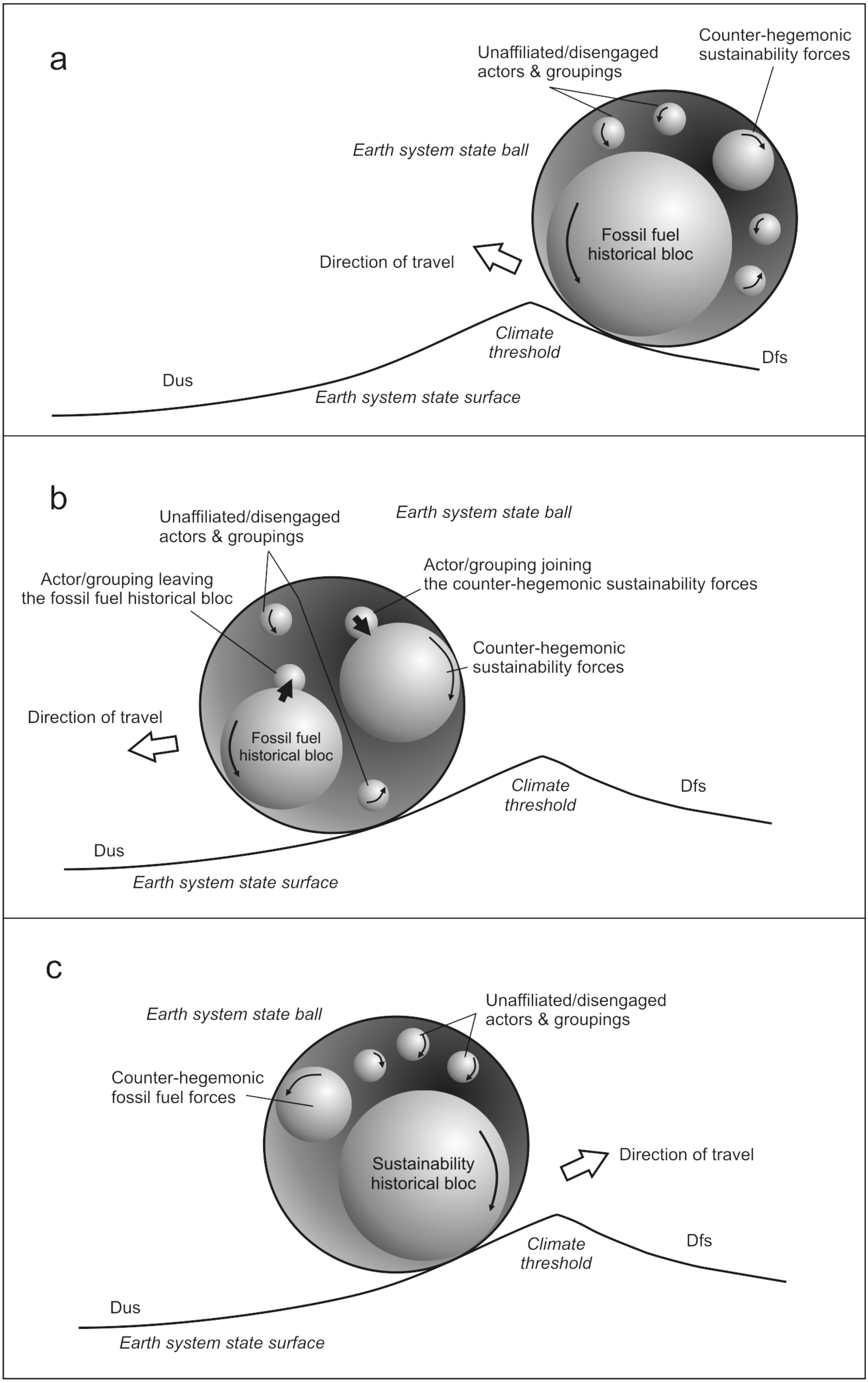
a
Unaffiliated/disengaged actors & groupings
Counter-hegemonic sustainability forces
Earth system state ball
Fossil fuel historical bloc
Direction of travel
Climate threshold
Dus
Dfs
Earth system state surface
b
Unaffiliated/disengaged actors & groupings
Earth system state ball
Actor/grouping leaving the fossil fuel historical bloc
Actor/grouping joining the counter-hegemonic sustainability forces
Counter-hegemonic sustainability forces
Direction of travel
Fossil fuel historical bloc
Climate threshold
Dfs
Dus
Earth system state surface
c
Earth system state ball
Unaffiliated/disengaged actors & groupings
Counter-hegemonic fossil fuel forces
Sustainability historical bloc
Direction of travel
Climate threshold
Dfs
Dus
Earth system state surface

Fig. 1 Political contestation over a social-ecological system state's path: Getting inside the ball

The three panels (**a**, **b** and **c**) show (beginning at circa 2010) change over a few years in the state of the Earth system and the role of political contestation over climate change mitigation in system state change. Actors and groupings are represented in relation to political contestation by internal balls inside the system state ball, beginning with a *fossil fuel historical bloc* ball, *counter-hegemonic sustainability forces* ball, and smaller *unaffiliated or disengaged actors and groupings* balls. A climate threshold in the surface is represented, separating the fringes of two stability domains representing two possible stable Earth system states: Dfs (Domain: familiar; stable) and Dus (Domain: unfamiliar; stable).

a Now, circa 2010, fossil fuel hegemony: The fossil fuel historical bloc ball is the largest internal ball, reflecting the fossil fuel historical bloc's dominance of the Earth system state. The fossil fuel historical bloc ball is shown spinning (direction indicated by the longer arrow) within the system state ball. By virtue of its dominance, the fossil fuel historical bloc ball sets the direction taken by the larger system state ball (from right to left - large open arrow), and drives the system state ball's movement across the system state surface. The counter-hegemonic sustainability forces are represented as the next biggest ball, coalesced around shared perceived and actual interests that are in opposition to continued human social reliance on carbon-dependent economic growth, i.e. in opposition to those interests that draw together the actors and groupings comprising the fossil fuel historical bloc. The counter-hegemonic sustainability forces ball is also spinning (arrow indicates direction), but in a different direction. Counter-hegemonic sustainability forces are attempting (unsuccessfully so far) to drive the system state in a direction other than that of the fossil fuel historical bloc. Unaffiliated or disengaged actors and groupings balls are also visible, spinning (arrows indicate direction) generally in a direction that is consistent with that set by the fossil fuel historic bloc (i.e. the *status quo*). Unaffiliated or disengaged actors and groupings accept the fossil fuel historical bloc's interests as the broader societal interest, consistent with the fossil fuel historical bloc's hegemonic dominance of the system state. Unaffiliated or disengaged actors and groupings are of little consequence for the path taken by the system state ball.

b Near future, a shift in contingent hegemonic stability: The system state ball has been driven outside of Dfs, up and over the climate threshold and into the alternative stable state Dus. However, one feature of contingent hegemony is continually negotiated alliances between actors and groupings. An actor/grouping no longer perceiving its interests as consistent with those of the fossil fuel historical bloc is shown withdrawing from the fossil fuel historical bloc, leading to a weakening in the fossil fuel historical bloc's hegemonic dominance of the system state, reflected in the reduced size of the fossil fuel historical bloc ball. Another actor/grouping is beginning to perceive its interests as consistent with those of counter-hegemonic sustainability forces. The ball representing this actor/grouping is shown joining with the counter-hegemonic sustainability forces, leading to a strengthening of the counter-hegemonic sustainability forces, reflected in the increased size of the ball representing counter-hegemonic sustainability forces. At this time, the fossil fuel historical bloc remains the dominant influence on the system state and continues to drive the ball's path across the surface (large open arrow). Unaffiliated or disengaged actors and groupings remain of little consequence to the path taken by the ball.

c A little later, turning around the system state: Substantial changes in the comparative position of political economic actors/groupings have occurred modifying the system state ball's path. Counter-hegemonic sustainability forces have been enlarged by additional actors/groupings, such that a new sustainability hegemony has come to dominate the system state. This new *sustainability historical bloc* ball is now the largest, reflecting its newly attained dominance of the system state. The sustainability historical bloc's dominance of the system state is driving the system state ball in a new direction: from left to right, i.e. across Dus to cross the climate threshold and returning to Dfs. Actors/groupings that once constituted the fossil fuel historical bloc have continued to perceive their interests as inconsistent with those of the previous hegemony and have left the fossil fuel historical bloc. The remaining fossil fuel actors/groupings now comprise a counter-hegemonic force, and their reduced influence on the system state is reflected in the reduced size of the newly-labelled *counter-hegemonic fossil fuel forces* ball. Again, unaffiliated or disengaged actors and groupings are of little consequence to the path taken by the system state ball.

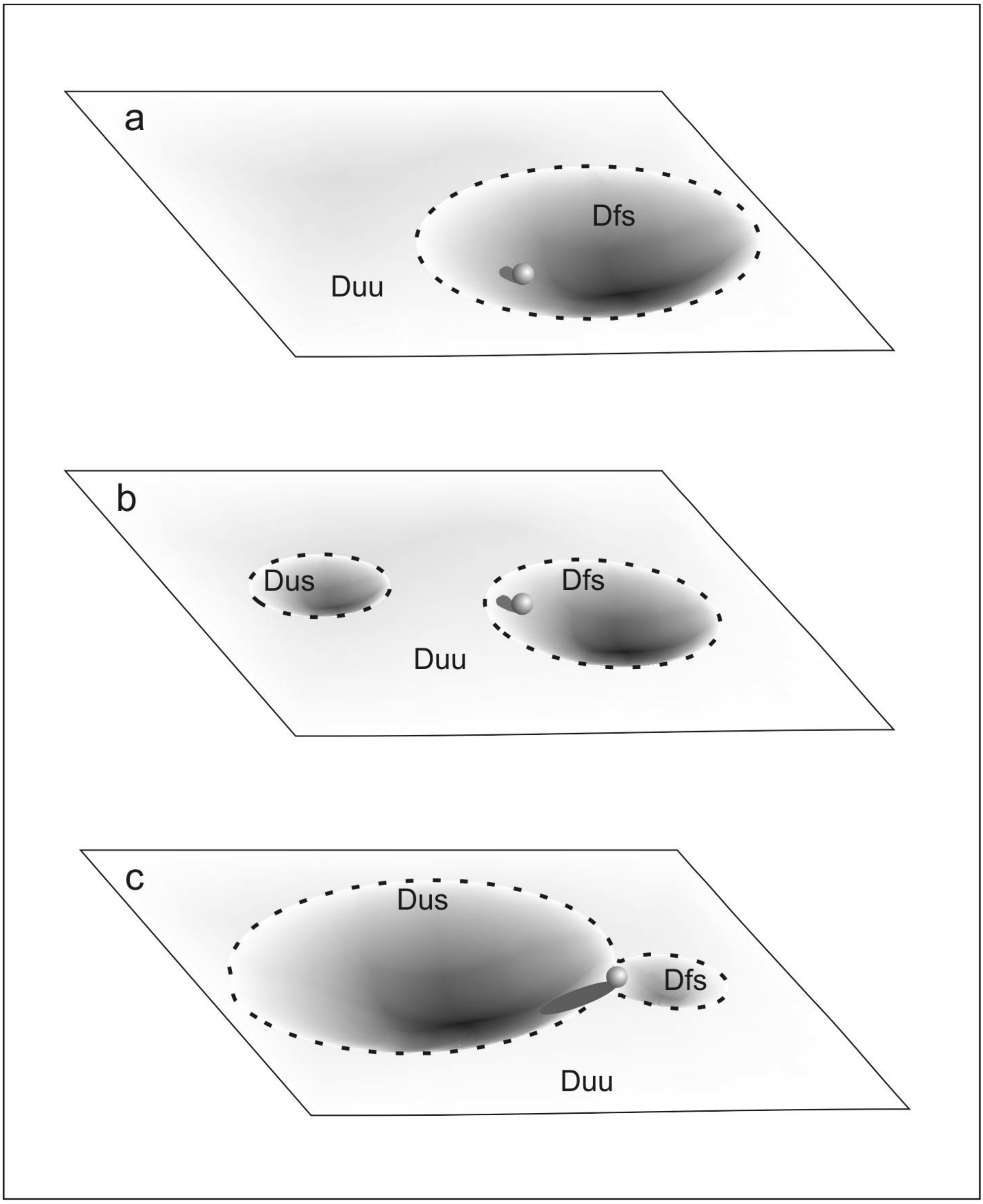

Fig. 2 Hegemony and climate disruption in the Earth system: Distortions in a dynamic system state surface

Three panels (**a**, **b** and **c**) show the impact of cumulative greenhouse gas emissions over ~160 years on the stability and potential for stability of the Earth system, depicted as changes in the features of the surface. The two stability domains: Dfs (Domain: familiar; stable) and Dus

(Domain: unfamiliar, stable) from Figure 1 are placed in an infinite surface depicted as flat and designated Duu (Domain: unfamiliar; unstable). A dotted line delineates the thresholds between domains.

a Before anthropogenic climate change (circa 1850): The Earth system state surface with one key feature: the large stability domain Dfs, i.e. the Earth system state domain that is familiar (to humans and our civilisations) and stable. The system state ball is deep in the cup.

b Early anthropogenic climate change (circa 1950): Anthropogenically increased atmospheric greenhouse gas concentrations causing climate change have led to the creation of a large new potential stability domain for the Earth system. Dus is an unfamiliar domain, and one that is also stable. Increased atmospheric greenhouse gas concentrations have also constrained the Earth system's current stability: Dfs has decreased in size and is now narrower and shallower. A reduced Dfs leaves the system state ball in closer proximity to the edge of Dfs. Whilst the ball remains in Dfs (and therefore the Earth system remains stable), its location closer to the edge of the cup represents reduced system resilience, i.e. a smaller change would see the ball's location outside of stability domain Dfs.

c Later anthropogenic climate change (circa 2010): Continued increases in atmospheric greenhouse gas concentrations drives climate change and further reduces the size of Dfs leaving the system state ball even closer to the edge of the Dfs. Simultaneously, Dus has enlarged considerably, to the extent that a potential passage for the system state ball across a climate threshold from Dfs to Dus is created in the system state surface.

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8. Research findings and discussion

'…we make the world we live in with one another' (Stuart Kaufmann, in Waldrop 1994, p.321)

8.1 Introduction

The crisis of anthropogenic climate change is real and urgent. As a human-driven social-ecological phenomenon of the Earth system, and a highly charged political challenge, it can be addressed successfully only through effective social change. Such a change is unprecedented in human history, and the future is uncertain. Nevertheless, uncertainty is not necessarily 'bad': uncertainty suggests possibilities. Human societies have experienced numerous episodes of substantial upheaval, and earlier grand justice struggles offer useful models of desirable change. Whilst the path to achieving effective and just mitigation of anthropogenic climate change remains unclear, the analysis provided in this PhD, including the new conceptual framework proposed in Chapter Seven (paper E), may offer a constructive contribution to achieving a sustainable and just future for humanity.

This PhD began in pursuit of three overarching research aims, recast as six specific research questions (Section 1.2). This chapter begins by making explicit the manner in which the intent of the research project has been pursued. Section 8.2 summarises the findings of this PhD in response to the overarching research aims. Some discussion of the research's findings is included in each of the stand-alone papers. Section 8.3 provides additional discussion of the findings and the research process undertaken to achieve them. This research project also suggests several potential lines of further inquiry, and these are outlined in Section 8.4.

8.2 Research findings

8.2.1 First research aim: What does anthropogenic climate change mean for the insurance system?

The first overarching research aim addressed the anthropogenic climate change-insurance system, and was devolved into two specific research questions (1.a and 1.b). The first focussed on whether anthropogenic climate change may be a threat to the insurance system, and if so what kind of a threat it may entail. The second considered the possibility that anthropogenic climate change may be an opportunity for the insurance system. As discussed in Chapter Three (including paper A), anthropogenic climate change remains unmitigated, and it appears it will remain so for the foreseeable future. Unmitigated anthropogenic climate change threatens the familiar stability of the Earth system, and therefore all of human socio-economic systems are vulnerable. It follows that anthropogenic disturbance to the climate is a threat to the insurance system. This conclusion is important in two respects. Firstly, the literature on the anthropogenic climate change-insurance system relationship suggests the possibility of the opposite: that the insurance system, or elements within it, such as commercial insurers, may be able to 'ride out' climate risks, for example through instituting adaptation-style measures, such as increasing premiums, limiting claims, or ultimately denying access to coverage. Secondly, and perhaps flowing from this faulty logic, and as noted in Chapter Four (paper B), the strongest insurance system responses to anthropogenic climate change are adaptive and weakly mitigative, *i.e.* not providing for strong mitigation action.

Such strategies may provide comparative advantage to some components of the insurance system, and for a limited period, *i.e.* whilst the strategies remain viable. However, as flagged in Chapter Four (paper B) and explored more fully in Chapter Five (paper C), such strategies play out wholly within the insurance system-global economy relationship. They have no direct impact on the source of accumulating climate risk: the relationship between the global economy and the Earth system. The scale and magnitude of anthropogenic climate change as an Earth system phenomenon limits the potential to avoid climate risks without addressing the cause of anthropogenic climate change.

The effect of the insurance system's adaptive responses to changing climate risks may also have serious negative and indirect impacts. As discussed particularly in Chapter Five (paper C), some currently-employed adaptation measures, for example shifting climate risk from the insurance system up a scale to the global economy via catastrophe bonds issued onto capital markets, are a double-edged sword. On the one hand, such measures increase the insurance system's short term capacity to assume climate risks. On the other hand, shifting risk up a system scale without addressing the continuing accumulation of climate risk means that systemic failure becomes more likely, and that in the event of its occurrence it will be larger-scale, and therefore more profound. This critique of adaptive insurance responses is discussed further in Section 8.3.

This thesis completes its response to the first research aim by considering the potential for anthropogenic climate change to present an opportunity to the insurance system. The potential for commercial elements in the insurance system to continue to profit even as climate risks increase, and at the cost of large non-insured populations, is a possibility raised in the literature (Paterson 2001, pp.36-38). However, given the comprehensive threat that anthropogenic climate change presents, and particularly increasing Earth system instability, the CASs analysis developed in this thesis argues that to the extent that opportunities exist they will be extremely limited, likely to be small, and, at best, transient. Opportunities for insurers to profit through adaptive and weakly mitigative actions (see Mills and Lecomte 2006; Mills 2007, 2009) will be similarly circumscribed.

Chapter Six (paper D) presents an alternative approach to this research aim: anthropogenic climate change mitigation as a potential opportunity for the insurance system. This opportunity is grounded in mitigation (as opposed to anthropogenic climate change itself), and identifies a key role for the insurance system in that endeavour. Such an approach contrasts significantly with current insurance system responses to increasing climate risks. The proposal articulated in Chapter Six (paper D) invites further development; it contributes to this research as a theoretical application of the reflexive mitigation concept developed in Chapter Five (paper C).

8.2.2 Second research aim: How might the insurance system be oriented towards effective and just anthropogenic climate change mitigation?

The second overarching research aim (Section 1.2) addressed the issue of whether the insurance system might be oriented towards effective and just mitigation of anthropogenic climate change. The second research aim was also devolved into two specific questions. These addressed firstly (2.a) the character of insurance system responses to date to anthropogenic climate change, and (2.b) the potential for the insurance system to engage in strong mitigation action.

The thesis' response to this pair of research questions overlaps with responses to the first overarching research aim. In relation to question 2.a, the research finds that even the strongest insurance system responses to anthropogenic climate change have been adaptive and weakly mitigative, as opposed to strongly mitigative, as explored in Chapter Four (paper B). The analysis provided in Chapter Five (paper C) explains the limitations of adaptive and weakly mitigative insurance system responses. Chapter Five (paper C) also articulates a theoretical transition for the insurance system from a linear to a non-linear basis.

In relation to question 2.b, the research finds that whilst the insurance system is yet to engage in strong mitigative action, there is at least the theoretical potential for it to do so. The proposal in Chapter Six (paper D) for an insurance basis for carbon prices is presented as an example scenario in which the insurance system engages in strong mitigation action. The proposal extends the CASs analysis flagged in Chapter Four (paper B), and undertaken in Chapter Five (paper C). The proposal completes a shift in this PhD research from problem identification to solution creation.

Nevertheless, achieving such a radical shift in the insurance system's stance in relation to anthropogenic climate change presents serious challenges. The CASs approach comprising three systems and relationships among them developed for this study has proved useful in identifying the theoretical opportunity anthropogenic climate change mitigation provides the insurance system. However on its own, the CASs analysis falls short in addressing the political dimensions of anthropogenic climate change and its mitigation.

8.2.3 Third research aim: How might reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship contribute to further development of complex adaptive systems approaches?

The third overarching research aim (Section 1.2) calls for reflection on the application of a complex adaptive systems (CASs) approach to the anthropogenic climate change-insurance system relationship. Moving to consideration of the application of the CASs approach in this PhD represents the second research shift, from solution creation to reflection on the use of theory. The third research aim invites consideration of possible insights generated through the research that may be useful for the ongoing evolution of the CASs approach more broadly. The third research aim was also broken down into two specific research questions to identify both (3.a) limitations of the CASs approach as applied in this instance and (3.b) the potential to further CASs approaches by seeking to overcome limitations revealed through application of the CASs approach in this instance.

This thesis has identified potential to strengthen existing theoretical approaches to political contestation in SESs – such as the Earth system – in a time of systemic crisis. The thesis has responded to the third research aim by proposing a new conceptual framework that links two disparate concepts: resilience and hegemony. A CASs approach to social-ecological systems has coalesced around the concept of resilience, together with vulnerability and adaptability, and has come to be referred to as 'resilience thinking'. The new conceptual approach presented in Chapter Seven (paper E) is proposed in order to overcome the currently limited capacity of resilience approaches to address the power and normative dimensions of social-ecological systems. Linking the theories may also support continued development of critical political economy analyses as applied to crises of global environmental governance. However this direction is not explicitly developed in this study.

8.3 Discussion of this research

This section discusses the several important responses produced by the research in this PhD to the three overarching research aims as originally defined. Achieving the research findings noted above required a novel and original transdisciplinary research design that allowed exploration and application of complex adaptive systems approaches, critical political economy, some sociology of risk, as well as climate and Earth system science, including a technique borrowed from epidemiology for dealing with probabilities.

Relationships amongst three complex adaptive systems at the global scale provides a challenging subject for inquiry. The transdisciplinary research design, the sustainability science tradition, and the complex adaptive systems approach provided mutually reinforcing reference points for the study, and so supported the PhD's exploration of the insurance system, the global economy, the Earth system, and the relationships among them. The study's overarching research aims were addressed through: (i) identifying and characterising the problem anthropogenic climate change presents for the insurance system; (ii) proposing a solution in response to the problem; and (iii) generating a new conceptual framework arising from reflecting on the application of theory in this instance.

Reflection on the course of the research process suggests several new understandings that were not apparent at the beginning of the study. Sustainability science provided a rationale for the research, a way to identify a problem, as well as legitimation of problem-based scientific inquiry. The CASs approach provided a framework for the problem as a subject of inquiry. Lastly, the transdisciplinary research design provided a way to conduct the research through its various stages, from problem identification through solution creation to reflection on application of theory.

In some respects, the research conclusion that unmitigated anthropogenic climate change presents a permanent, strategic and potentially existential threat to the insurance system is not wholly unexpected. Anthropogenic climate change is an unprecedented challenge to human societies. Certainly, the climate and Earth systems science literature makes this argument clearly and powerfully (*e.g.* Hansen *et al.* 2008; Rockström *et al.* 2009; Solomon *et al.* 2009). Yet insurance system responses to anthropogenic climate change are only adaptive and weakly mitigative. This research explores the political economy explanation for limitations to responses to accumulating climate risks from commercial elements of the insurance system.

In Chapter Five (paper C), adaptive responses to anthropogenic climate change are described as being akin to business-as-usual. Attempting to adapt to changes in circumstances is normal practice for human beings, our institutions, and for other living things. This is not to say that adaptation is not important. Impacts of anthropogenic climate change are already manifest, and will continue to accumulate as long as the Earth system continues to change. However, the nature of adaptive measures requires careful consideration.

Lebel *et al.* (2009, p.126) argue that existing and 'persistent social injustices [can] be made worse by inaction and misguided climate change adaptation policies'. Barnett and O'Neill (2010) also consider the potential for adaptive actions to be counter-productive, rather than simply ineffective. Barnett and O'Neill (2010, p.211) define maladaptation as 'action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups'. These authors further propose 'at least five distinct types or pathways through which maladaptation arises'. Maladaptive responses to anthropogenic climate change are actions that (relative to alternatives): (i) 'increase emissions of greenhouse gases'; (ii) 'disproportionately burden the most vulnerable'; (iii) 'have high opportunity costs'; (iv) 'reduce incentives to adapt'; and (v) 'set paths that limit the choices available to future generations' (Barnett and O'Neill 2010, p.211).

Maladaptation is far removed from the adaptation with grace concept, as proposed in Chapter Five (paper C). Chapter Four (paper B) describes adaptive (and weakly mitigative) insurance system responses to anthropogenic climate change. For example, consider changes in the insurance system such as shifting financial risk outside of the insurance system and onto capital markets. This innovation originated in response to earthquake risks and not as an adaptation to changes in weather risks. This action is adaptive in the context of anthropogenic climate change in that it allows the assumption of greater climate risk in the shorter term. However, it does so at the cost of increased future climate risk by indirectly increasing greenhouse gas emissions, to the extent that the insurance system facilitates continued operation and expansion of the carbon-based economy, and therefore greenhouse gas emissions. In that sense such an adaptation may be better described as maladaptation.

The maladaptive role of the insurance system in facilitating continued and increased emissions, *i.e.* business-as-usual for the global economy, is not a neat fit with any of Barnett and O'Neill's (2010) five maladaptation types. Two of the types suggest potential for a fit, but ultimately fall short, principally through their focus on adaptation to the exclusion of potential links between adaptation and mitigation. The scale of their application also contributes to the mismatch. Barnett and O'Neill's first type, 'increase emissions of greenhouse gases', refers to specific, local-scale actions, for example the commissioning of fossil fuel energy-intensive water desalination plants to ensure potable water supply in the face of climate-implicated shortages (Barnett and O'Neill 2010, p.212). Similarly, the fifth type, 'set paths that limit the choices available to future generations' is also used to describe specific, local scale actions, as opposed to providing a broader-scale analysis. Barnett and O'Neill's listing of 'at least five distinct types' (Barnett and O'Neill 2010, p.211) may perhaps be usefully augmented by a sixth type of maladaptation: adaptive actions that reduce incentives to mitigate.

Adaptation is not the only anthropogenic climate change response option available to the insurance system. This PhD research proposes reflexive mitigation in Chapter Five (paper C) as a conceptual basis for a strong mitigation response to anthropogenic climate change. Chapter Six (paper D) proposes an insurance basis for carbon prices as a theoretically viable role for the insurance system that reflects the reflexive mitigation concept. Mitigation of anthropogenic climate change is not solely the responsibility of the insurance system, but neither is mitigation an achievable objective without engagement across human societies, *i.e.* including the insurance system.

Effective and just mitigation is an unprecedented challenge. Chapter Three (including paper A) spells this out clearly. Chapter Seven (paper E) provides a new conceptual framework that better characterises anthropogenic climate change as a global-scale injustice in the Earth system. Chapter Seven makes plain the high stakes that are at play in the political struggle to mitigate anthropogenic climate change: nothing less than life as we know it on planet Earth. Chapter Seven also makes explicit the nature of the political challenge that mitigation entails. Anthropogenic climate change is by definition a problem of our own making. Just as climate change is anthropogenic, so too will be its mitigation.

8.4 Directions for further research

This thesis has aspired to address the three overarching research aims recast as six specific research questions articulated initially in Section 1.2. In so doing, the thesis has raised several promising and important options for further research.

Firstly, the thesis suggests opportunities for further research in relation to insurance and anthropogenic climate change. Research on the extent to which continued application of adaptive and weakly mitigative insurance system approaches facilitate continued accumulation of climate risk and, thus, may create larger system impacts in the future is an important area for consideration. The proposal for an insurance basis for carbon pricing also invites further development. So too do the concepts of reflexive mitigation and adaptation with grace.

Secondly, a related line of research inquiry could usefully explore scenarios for the future of the insurance system as an important element of the global economy. As noted in Chapter Five (paper B), much of the world's population lives without direct access to insurance. Nevertheless, insurance is a key part of the global economy as currently constituted: significant changes to the insurance system imply significant changes to the global economy.

Thirdly, the CASs approach, as applied to insurance, could be extended to other global-scale subsystems of the economy, for example the energy system, the transport system, and the health system. The research in this thesis additionally suggests potential for further work in relation to the implications of increasing uncertainty associated with anthropogenic climate change for governance of human societies.

Lastly, perhaps the broadest potential for further research stems from the conceptual framework developed and presented in Chapter Seven (paper E). Whilst the path to this conceptual framework was via inquiry into insurance, the approach is more generally applicable. Combining hegemony with resilience could be applied to other environmental governance questions, at varying scales. The power and normative implications of complexity theory more generally also merit further study.

9 Conclusion: Insurance in the Anthropocene

> Tangible victories matter… Yet we won't always win, so we need ways to persist no matter what the outcome. The more we accept we can't control all the results of our actions, the more we free ourselves to keep doing the work that seems most necessary (Loeb 2004, p.322).

Three and half years ago, almost to the day, I began this study into the relationship between anthropogenic climate change and what I have come to call the insurance system. As noted in the Preface, before then I had been working on international finance institutions, engaged in civil society campaigns to limit the most deleterious impacts of proposed infrastructure developments in low income countries. Through that work I became aware of the facilitative potential of insurance. Through that work I also developed awareness of anthropogenic climate change. That was my path to this research project.

The conclusions from this PhD are sobering. Despite decades of scientific research, international negotiations, and growing popular understanding globally, humanity is yet to effectively and justly mitigate anthropogenic climate change. Anthropogenic climate change threatens human social systems generally, including the insurance system. Insurance system responses to anthropogenic climate change remain far from adequate, generally geared to facilitate continuation of business-as-usual, *i.e.* adaptation, in the face of rising levels of climate risk. More alarming still, some adaptive insurance system responses extend beyond inadequacy to perversity. For example, by shifting climate-implicated financial risks to capital markets in order to assume greater risk-bearing capacity in the short term, while not dealing with the origins of increasing climate risk, the insurance system currently is exacerbating rather than eliminating future climate risks. This threatens human societies in general, including the insurance system.

This PhD provides an insurance basis for carbon prices as one theoretically viable example of strong mitigation action by the insurance system. There may well be others. The insurance system plays a key societal role in risk governance. Failure to mitigate anthropogenic climate change raises serious implications for the ongoing viability of the insurance system, and for human societies more broadly.

The loss of familiar Earth system stability does not necessarily mean the end of the insurance system. However, loss of familiar Earth system stability does undermine the current linear basis for the insurance system. A functioning insurance system in a relatively unstable Earth system may or may not be recognisable in comparison to the insurance system's current form, function and scale.

Atmospheric concentrations of greenhouse gases have continued to accumulate increasingly rapidly, together with climate impacts and risks. In varied ways, human communities and societies are currently crossing a cascading series of tipping points: even though we are still to act effectively on mitigation, the need for adaptation actions is now also upon us. Yet even as the immediacy of the need for adaptation action becomes all too apparent, the urgency for mitigation increases. Mitigation and adaptation are helpfully understood as complements, rather than trade-offs (Schneider 2010). Clearly both things need to happen. Both are urgent. But whilst adapting with grace to anthropogenic climate change is an extraordinary challenge, it is a challenge that is wholly dependent on successful mitigation.

In the Discussion in Chapter Eight I referred to the notion of maladaptation, and Barnett and O'Neill's (2010) criteria for defining maladaptive actions. In closing, let me turn that notion around and extend it a little further, perhaps provocatively, by asking this question: in the absence of successful mitigation, what adaptation measures do not constitute maladaptation? What options for adaptation action are available to us that will not conform to at least one of the criteria for maladaptation?

Mitigating anthropogenic climate change is not only a challenge for the insurance system, but for human societies generally. Mitigation is difficult and there is no 'work around', no alternative course. Not for the insurance system, and not for any other element of human society. Setting sights on mitigation means immediately making explicit the need for fundamental socio-economic changes. Phrases such as 'decarbonise the economy' speak to the technical dimensions of mitigation, but neglect the challenging political dimensions of achieving necessary radical social change. Mitigating anthropogenic climate change will surely require profound societal upheaval.

Linking the concepts of resilience and hegemony is useful to comprehensively explain both the character of the threat that anthropogenic climate change entails, as well as the profound political challenge it presents to human societies. This analysis is deeper than perspectives that focus on the potential for technological fixes, however broadly defined. And there are many fixes currently being touted, ranging from the deeply inadequate, such as emissions trading schemes and carbon taxes that remain adrift from ecological reality, through bizarre and dangerous diversions, such as the pipe dream of industrial-scale carbon capture and storage (Wilkenfeld *et al.* 2007), to the desperate, such as any number of geo-engineering proposals (Schneider 1996; Goodell 2010).

Combining resilience with hegemony also provides hope. It does so by illuminating one path to achieving mitigation, *i.e.* undermining the hegemonic dominance of the fossil fuel historical bloc. The path has already proven to be very difficult. So it will remain, as were the courses of earlier grand justice struggles. We may wish the world was not this way; but it is. Every important struggle is unique, and mitigating climate change is no exception, in terms of its character, scale, magnitude, and complexity. But it is in the earlier struggles for justice that we will find inspiration for how to effect the social change necessary to mitigate anthropogenic climate change now, and in the future.

The situation is grim. But is everything lost? Rebecca Solnit opens her (2004) book *Hope In The Dark* this way:

> On January 18, 1915, six months into the First World War, as all Europe was convulsed by killing and dying, Virginia Woolf wrote in her journal, "The future is dark, which is on the whole, the best thing the future can be, I think." Dark, she seems be saying, as in inscrutable, not as in terrible. We often mistake the one for the other. Or we transform the future's unknowability into something certain, the fulfilment of all our dread, the place beyond which there is no way forward. But again and again, far stranger things happen than the end of the world (Solnit 2004, p.1).

The situation is grim and there is much uncertainty. Without diminishing the loss and suffering wrought by the First World War during which Woolf wrote in her diary, or all the other wars which preceded and followed, I suggest unmitigated anthropogenic climate change threatens suffering at a greater scale – the planetary scale. Anthropogenic climate change is truly an unprecedented challenge, one that threatens familiar political and ecological stabilities.

Given that, the important questions for humanity are about the choices we make, the actions we take, and how we continue the struggle to mitigate anthropogenic climate change effectively and justly. The Earth system is a complex adaptive system, characterised by non-linear change. It is a social-ecological system, and one that is wracked by political and ecological crises of our own making. As ever, the justice of our choices and actions will make our futures.

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