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The impact of controversy on the production of scientific knowledge

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Abstract

Much of the existing literature employing the framework of controversy focuses on the science-policy interface. However a clear gap exists regarding the way(s) in which controversy may fundamentally shape the production of scientific knowledge itself. This research uses the debate about climate change as a case study to understand the impact of controversy on the production of scientific knowledge, focusing in particular on the interrelated elements of scientific practice and the agency of individual scientists. Based on 63 research interviews with climate scientists, "sceptical voices" about climate change and others, it finds that whereas the majority of climate scientists do not consider sceptical voices to have an impact on scientific practice, the vast majority do identify impacts on scientific agency. The predominant type of agency-related impact is increased caution, followed by disruption, a greater focus on communication, defensiveness and reluctance to publicly engage. It is argued that scientists' ability to distinguish between impacts on agency and practice is both a performative expression of Gieryn's (1999) notion of boundary work and a function of controversy, with the greater the impact of controversy, the less fluid and contingent the boundary between the two. Boundary work is thus a more active and explicit process under conditions of public scientific controversy, as scientists work to ensure the independence and unassailability of their cognitive authority in contested domains. Potential implications for epistemological norms and the social value of science are also identified.

Keywords:

Production of scientific knowledge, controversy, climate change, scepticism

1. Introduction

As a guiding paradigm, controversies have become an increasingly visible topic in the literature. They magnify and make explicit the 'normally hidden social dimensions of science' (Pinch, 2001: 13719) and highlight the ways in which factors such as political struggles or values debates can influence the role of science in society (Martin and Richards, 1995). To date, the vast majority of controversy-based research has focused on the ways in which scientific knowledge is used in, or shapes, the policy process (Wynn and Walsh, 2013; Beck et al., 2014; Landström et al., 2015). In particular, engagement between scientists and other social actors, such as the general public, politicians or knowledge brokers, appears to have been the dominant investigative avenue (Wolf and Moser, 2011; Knight and Lyall, 2013; Gluckman, 2014). This has however meant a concomitant lack of attention being paid to how controversy may fundamentally shape the production of scientific knowledge itself, particularly in terms of individual scientists' responses to controversy. This is a critical gap in the literature and is vital to understand for several reasons. Not only may the substantive knowledge gained within disciplinary boundaries be impacted (with, for example, subsequent ramifications for its use as an input to policy decision-making), but wider epistemological norms may also be influenced. These include the types of future scientific enquiry that are carried out, including the appropriateness of specific techniques or modes of investigation, or what the expectations are of scientists as actors in society, such as their role in public or political engagement (Nowotny, 1993; Delborne, 2008; Douglas, 2009). Furthermore, and directly relevant to current debates related to expertise and legitimacy (Suryanarayanan and Kleinman, 2013; Collins, 2014; Nisbet and Markowitz, 2014; Turner, 2014), is the need to understand how scientists are able to make sense of, and retain their cognitive authority in the face of controversy. Accordingly, this research examines the impact of controversy on both the 'material practices that embody the *work* of doing science' (Roosth and Silbey, 2009: 459, emphasis in the original) and on scientists' perceptions of their own agency as producers of scientific knowledge.[1] It thus follows in the footsteps of Latour and Woolgar (1986) by entering the "black box" of scientific knowledge production, and also responds to Longino's (2013) call for greater attention being paid by philosophers of science to 'individual rationality and individual knowledge' in terms of decisions made by scientists as discrete actors within the knowledge production process. It employs Gieryn's (1983; 1999) concept of boundary work to explain scientists' sense-making regarding their perceptions of impact, and provides a conceptual framework of the ways in which controversy may influence the scientific knowledge production process, focusing on the responses of individual scientists.

As has been recognised by many other authors in the field, climate change presents a particularly valuable case study for research into controversy and science (Demeritt, 2001; Demeritt, 2006; Beck et al., 2014; Jankó et al., 2014). Due to its socially-relevant yet complex nature, it illuminates the way that the social trust placed in science (and scientists) as creators of policy-relevant "facts" can be precarious under conditions of uncertainty. This research focuses on the experiences of climate scientists in two case study locations, New Zealand (NZ) and the United Kingdom (UK). While the majority of the public in both countries agree that climate change is predominantly anthropogenic in origin[2], debate about climate change science is still in evidence (Cooper and Rosin, 2014; Carter, 2014; Tranter and Booth, 2015). In addition to a general undercurrent of scientific contention, controversy also exists in the form of vocal sceptical voices[3] external to traditional modes of scientific enquiry (for examples of overarching arguments and associated framings in the climate debate see Knight and Greenberg, 2011; Capstick and Pidgeon, 2013; Matthews, 2015) and key events such as Climategate.[4]

The next section examines how the existing literature conceptualises responses of scientists under conditions of controversy, followed by outlines of both the climate change debate and the controversy occurring within the two case study locations. Section 5 presents the method and is followed by results, discussion and a conclusion.

2. Reactions to controversy

In order to understand how controversy may impact the production of scientific knowledge, it is necessary to understand how scientific knowledge comes to be created in the first place. Following Gieryn (1999: xii) the starting point is taken that science is an inherently cultural space, without 'essential or universal qualities' to enable easy definition of its borders. However, in order to structure this investigation, the focus on scientists as knowledge creators suggests attention should be paid to the fundamental and interrelated components of agency and practice. Scientists have active *agency* in their choice and employment of the component *practices* that constitute the "doing" of science. Yet these component practices are also mutually constitutive of scientists' behaviours or agency (Figure 1) in what Pickering (1992; 1993; 2010) calls the "mangle". However, outside of sociology of scientific knowledge-based approaches, Merton's (1973 [1942]) influential normative principles describing scientific enquiry, particularly those of disinterestedness and organised scepticism, arguably remain the dominant framing in both the physical science tradition (Kardash and Edwards, 2012; Bucchi, 2015; c.f. Kellogg, 2006) and in the general public's view of science (Jaspal et al., 2013). Within this traditional paradigm, pre-eminence is given to scientific practice, with scientists' agency also

framed as objective and instrumental rather than subjective or co-constructive. Scientists engage in a variety of—supposedly neutral and linear in fashion—activities in order to achieve scientific truth (Latour, 1993). These range from identification of a research topic through to public engagement (shown in a stylised fashion in Figure 2 which explicitly focuses on the activities of scientists within formally-designated epistemic communities such as universities). However, drawing inspiration from Mannheim (1936), more sociological understandings of the scientific knowledge production process such as from Gieryn (1999) above and Gibbons et al.'s (1994) theory of Mode 2 knowledge challenge this narrow framing and suggest that science is also a cultural practice, i.e. they bring agency to the fore. Thus the choices made at each step in Figure 2 are neither as straightforward in time or space as they may appear, and are inevitably shaped by a myriad of more subjective factors both internal and external to the research process (Nowotny et al., 2001). For example, Lacey (2015: 2) identifies five 'logically distinct, but temporally and causally entangled' moments of scientific activity, ranging from M_1, making decisions about methodology, through to M_5, applying scientific knowledge. He argues that whereas traditional conceptions of knowledge exclude the role of values at, for example M_1, the decision to adopt a particular methodology is an ethical and social choice and thus must be recognised as such.

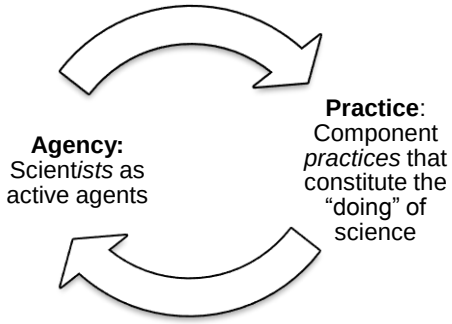

Figure 1: Relationship between agency and practice within the scientific knowledge production process

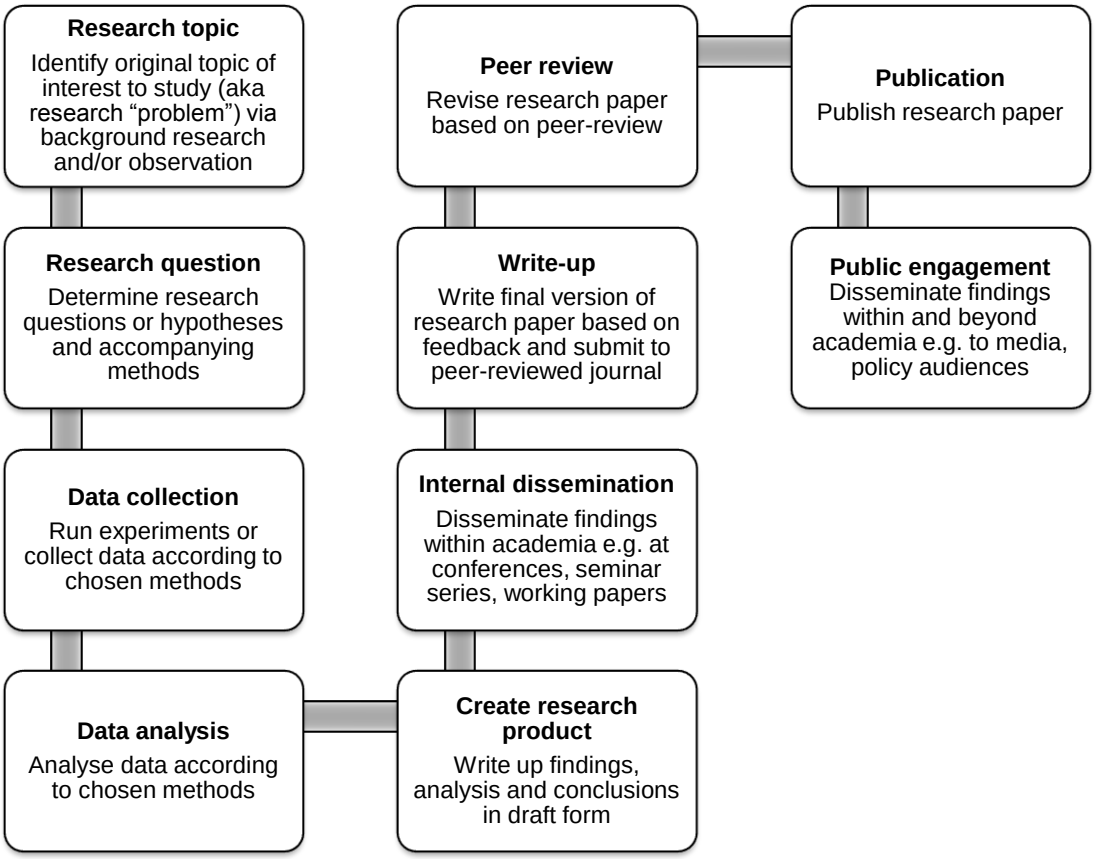

Figure 2: Stylised scientific knowledge production process

But how may controversy influence this interplay of agency and practice within the scientific knowledge production process? More socially-attentive interpretations suggest that scientific knowledge claims can be understood as being assembled to support opposing points of view (Pawson, 2006; Sharman and Holmes, 2010), with the "truth" of such claims heavily contested (Sarewitz, 2004; Gulbrandsen, 2008). Epistemic dominance by particular actors in a contentious debate also plays an important role in determining knowledge legitimacy and the resonance of claims (Stehr and Grundmann, 2011; Suryanarayanan and Kleinman, 2013). Factors such as competing values and ideologies (Jasanoff and Wynne, 1998; Douglas, 2009), or varied interpretations of uncertainty (Landström et al., 2015) contribute to the ways in which such claims come to exist and be employed within debate. Moreover, as scientific knowledge is understood to vary in certainty, appeals to uncertainty evident in controversial situations (Skinner et al., 2014) indicate the likelihood of controversy having a differential impact across the scientific process, including the generation of scientific knowledge claims. Controversy may have a stronger influence on more fluid forms of knowledge, such as the difference between the tentative nature of hypotheses versus the more immutable character of scientific laws, or those less deeply rooted in epistemological norms. For example, attempts to manufacture doubt over

the legitimacy of climate science in general (Oreskes and Conway, 2010) have frequently occurred via uncertainty-based challenges to the notion of a consensus (Montford, 2013; c.f. Lewandowsky et al., 2013). Truth is created by moving knowledge up the hierarchy of facticity (Latour and Woolgar, 1986), therefore it is unsurprising that consensus-making has been particularly liable to challenge as a way of delegitimising its influence as an authoritative discourse. But what about impacts on individual scientists as key actors within the knowledge production process? Scientists' decisions shown in Figure 2, such as where to site an experiment, what methods to use, or how to appropriately analyse results, are critical to address not only in terms of what they may say about *individual* scientists' agency and practice, but also because they may all be regarded as contributing towards the creation and embedding of (more or less explicit) disciplinary theories and norms (Sandoval and Reiser, 2004).

The existing literature suggests that controversy may influence the scientific knowledge production process, and in particular, the responses of individual scientists, in a variety of ways. Hilgartner (1990) finds that scientists may speak out in defence of their own or colleagues' work when criticised, whereas Negru (2013), examining economists' practices, argues that they have been found to shift the blame for disciplinary shortcomings to other factors. While much of the literature is imbued with a certain normative tone that controversy is uniformly negative, the independent review of Climategate led by Sir Muir Russell (2010) underscored the possibility for increased transparency following controversy. Another strand of research focuses on scientists' resistance to controversy, with scientists either actively (or passively) ignoring controversy (Oliver, 2001) or being unwilling to share data, particularly when requesters are deemed troublesome or with an ulterior motive (Swallow and Bourke, 2012). Gieryn's (1983; 1999) notion of boundary work is also relevant, defined as 'the discursive attribution of selected qualities to scientists, scientific methods, and scientific claims for the purpose of drawing a rhetorical boundary between science and some less authoritative residual non-science' (Gieryn, 1999: 4-5). This concept implies that scientists may respond to controversy by creating expertise-based boundaries between themselves as holders of a special type of cognitive authority and less legitimate "non-scientists". Controversy may result in changes to overarching professional norms within a discipline, as found by Boykoff and Boykoff (2007) when examining journalists' behaviours, and scientists may also be unwilling to discuss or complain about personal or institutional attacks for fear of reprisals or further incidents (Illman, 2005). What is however also critical to mention is that responses can differ according to the controversy itself. Areas of science that are very public or controversial are likely to impact scientists in different ways to those which are, for example, less immediately policy-relevant or which have less costly ramifications. Whereas the veracity of evolution may be a contested topic

in certain environments (Berkman and Plutzer, 2010), it seems unlikely that evolutionary biologists will be personally or professionally impacted by public scientific controversy in the same ways as may a medical researcher using animal subjects (Illman, 2005), an epidemiologist publicly visible in the vaccination debate (Deer, 2011), or a climate scientist. Furthermore, the individual characteristics of a scientist, such as the type of work they do within a discipline or their level of public engagement, are also likely to be very relevant to the impacts experienced under conditions of controversy.

In addition to the above, three further pieces of research are particularly relevant to this study and worthy of discussing in further detail. Lewandowsky et al. (2015), Kempner et al. (2011) and Kempner (2008) introduce the concepts of seepage, forbidden and nonknowledge, and the chilling effect, respectively. Lewandowsky et al. (2015) suggest that in response to controversy, scientists experience a variety of cognitive and social processes, notably prolonged stereotype threat (feelings of anxiety when reminded of a stereotype held against the group to which they belong), pluralistic ignorance (when those who hold the majority opinion believe they are actually in the minority when a marginal opinion is dominant in public discourse or the media), and third person effect (belief that one is less susceptible to social manipulation than others). They suggest that climate scientists' use of the terms "pause" or "hiatus" to refer to the late 20th century-early 21st century period of global mean surface temperatures is 'a departure from standard scientific practice and is indicative of seepage' (2015: 6), defined as 'the infiltration and influence of what are essentially non-scientific claims into scientific work and discourse' (2015: 2). However, no convincing evidence is presented to demonstrate the assumed relationship between scientists' use of these terms and seepage. For example it is suggested that these terms are a framing 'demonstrably created by contrarians' (2015: 6) and that scientists have, in response, tacitly changed the way they interpret data from that of variability to a pause or hiatus. Critically however, no traceable evidence is included as to the source of these terms (specifically, their supposed origin outside academia and subsequent uptake in the peer-reviewed literature). The overtly normative position that science ought to be somehow immune to value judgements, as well as so-called 'exogenous pressures' and 'non-experts' (2015: 9) is also concerning as it essentially disregards much of the literature regarding agency within the sociology of scientific knowledge approach that science is, in essence, a human process and that expertise remains a debated concept (Pinch and Bijker, 1984; Longino, 1990; Jasanoff, 2004; Stehr and Grundmann, 2011; Turner, 2014; Evans, 2015). Nonetheless, the question as to potential impact raised by Lewandowsky et al. is clearly relevant here and the paper's limitations emphasise the need for further research to investigate the impact of controversy in detail.

Kempner et al. (2011) suggest that controversy is an important element in the production of so-called "nonknowledge", that is, a factor that impedes the production of scientific knowledge. They argue that scientists learn from past scientific controversies that certain types of knowledge are deemed to be 'forbidden…too sensitive, dangerous, or taboo to produce' (2011: 476). While, due to its more demand-driven nature, the majority of climate change research differs to the examples provided (such as extra-sensory perception, argued to result in "career suicide" for the scientists involved, or socio-politically undesirable topics such as drug and alcohol harm reduction research), this concept is useful in that it indicates that it is possible that certain topics, parts of, or behaviours inherent to the scientific knowledge production process may be regarded as increasingly forbidden. Specifically, public engagement which requires breaching the protective barrier of the academic community, or committing criticisms or analytical strategies to forms liable to become publicly accessible (e.g. to emails which may be obtained through the provisions of freedom of information legislation), may be deemed to be inordinately risky. In a previous piece of research, Kempner (2008) finds that the overarching political environment can shape scientists' research practices via what she terms the "chilling effect" with self-censorship (of both specific terms and entire research topics) a common strategy when scientists had previously been involved in a public scientific controversy. However, she calls for more research into the details of exactly how scientists may respond to external political controversy. By focusing on the detail of changes to the material practices of science this research thus directly responds to Kempner (2008). It also goes further by not only examining impact on scientists in terms of their response to a controversial socio-political environment in general, but also in terms of response to interaction with individuals or groups who provide direct challenges to scientific legitimacy.

3. Debate about climate change

Debate about climate change is predominantly presented in both the media and the academic literature as a gaping dichotomy (McCright and Dunlap, 2011; Marquart-Pyatt et al., 2014), with two polarised sides at either end of a chasm of disagreement, claim and counterclaim (Knight and Greenberg, 2011). Scepticism as to the veracity of climate change science has been accused of deepening this gulf, both in terms of influencing public opinion or policy decision-making (Elsasser and Dunlap, 2013; Leiserowitz et al., 2013), but also by negatively impacting the production of climate science and its ability to be regarded as a legitimate input back into decision-making processes (Lahsen, 2008; Washington and Cook, 2011). This interpretation of what is commonly referred to as "climate scepticism" is alleged to impact individual climate

scientists in a variety of ways, from the requirement to disseminate (potentially controversial) findings interrupting 'their "real" work…[of] the production of knowledge' (Oreskes, 2014: 120) through to more direct and threatening personal attacks such as those sustained by individual climate scientists (Readfearn, 2012). These have included abusive emails as well as public accusations of so-called "scientific cleansing" of knowledge (Oreskes and Conway, 2010) and are contended to be attempts to question the entirety of climate science, via the discrediting of a few, higher-profile researchers (Mann, 2012). However these narratives are largely anecdotal. Thus not only is the representativeness of claims that scientists have been 'intimidated into neutrality by environmentalism's powerful opponents' (Lynas, 2005: 25) unclear, but the subsequent impacts of controversy on the production of climate science itself is also unknown. Not only is it important to understand how scientific knowledge which pertains to increasingly common, yet complex and "wicked" global issues such as climate change is influenced (Rittel and Webber, 1973; Lorenzoni et al., 2007), it is also of practical consequence as it serves to highlight how scientists and sceptical voices are interacting to alter the course of what is known, and not known, about the changing climate.

4. Geographies of contestation

Painter (2011) argues that climate change scepticism is largely an Anglo-Saxon phenomenon, and Capstick and Pidgeon (2013) find that epistemic scepticism (i.e. disputes about the scientific basis of climate change) is a key argument expressed in public discourse. Both NZ and the UK have recently experienced notable epistemic controversies about climate change, making them ideally suitable as case studies for understanding the impact of controversy on the production of scientific knowledge. In NZ, a small group known as the NZ Climate Science Coalition (NZCSC) formed in 2006 to provide New Zealanders with 'balanced scientific opinions that reflect the truth about climate change and the exaggerated claims that have been made about anthropogenic global warming' (NZCSC, 2007). Operating predominantly at the fringes of the public debate, in 2010 the NZCSC entered squarely into public view by forming the NZ Climate Science Education Trust (NZCSET) and filing a statement of claim in the NZ High Court asking to invalidate the official NZ temperature record kept by the National Institute of Water and Atmospheric Research (NIWA), a Crown Research Institute (CRI)[5] (NZCSC, 2010). In the ensuing court case (NZCSET v NIWA [2012] NZHC 2297) the judgement was handed down in favour of NIWA, with costs also awarded to the defendant (NZCEST v NIWA [2012] NZHC 3560) although it is unlikely that this will be paid given the liquidation of the NZCSET at the end of

2013 (Insolvency and Trustee Service, 2014; Kilgallon, 2014). Hereafter these legal proceedings shall be referred to as the NIWA-CC (court case).

The UK experience has been more extensively covered in the academic literature, although focus has predominantly been directed towards its representation in the news media (Carvalho and Burgess, 2005; Nerlich et al., 2012; Painter and Ashe, 2012). Climategate is widely regarded as a critical moment in the UK climate debate in terms of a challenge to scientific process, and has been subject to numerous analyses, including from a science and technology studies perspective (Ryghaug and Skjolsvold, 2010; Ravetz, 2011; Grundmann, 2012; Ramírez-i-Ollé, 2015) and in terms of its impact on public perceptions of climate change (Koteyko et al., 2012; c.f. Anderegg and Goldsmith, 2014). While the person(s) behind Climategate have never been identified, epistemic scepticism in the UK is also expressed in online forums such as blogs (Sharman, 2014) and by publicly visible organisations, such as the Global Warming Policy Foundation (GWPF)[6] (Painter, 2011).

5. Method

Sixty-three semi-structured interviews were conducted between November 2012 and March 2014 across the two case study locations. In-depth discussion enabled a comprehensive appreciation of the rationales and experiences of the actors involved (Seidman, 2013); however, the large number of interviews and subsequent message saturation that ensued enabled critical analysis to occur. Interviews occurred across three main categories: climate scientist, non-climate scientist academic, and other (Table 1). Climate scientists were identified as those working in a university department of physics, geography, earth sciences or environment; or for a government-funded climate-related organisation. Of this category, 93% were PhD-level qualified and were chosen where possible to ensure a wide representation across engagement in the public climate change debate (ranging from very engaged to not at all), type or method of climate science undertaken (such as atmospheric, oceanographic, paleoclimate or statistical climate modelling) and seniority (full-professor level to less than 10 years' experience in the field). Non-climate scientist academics were involved in predominantly social science research on the topic of climate change specifically, or broader theoretical considerations relevant to this research such as the role of science in society. Finally, the category of other was used to classify a broad range of individuals such as journalists, industry or NGO representatives, as well as those identified as "sceptical voices" (who were also identified within the previous categories). This amalgam category of "other" and the lack of further detail regarding numbers of sceptical

voices within each category are deliberate choices in order to avoid more specific breakdowns that would likely lead to the identification of interview participants. Individuals referred to as a sceptical voice were identified from sources such as Painter's (2011: 128) 'list of sceptics 'mentioned' more than once in 10 UK national newspapers'; those associated with organisations such as the NZCSC and the GWPF, or, due to online sources increasing importance in the climate debate (Gavin and Marshall, 2011), from Sharman's (2014) list of climate sceptical blog authors. Of the 63 interviews, nine occurred in a UK-based pilot phase and assisted in subsequent interview design.

Table 1: Interviews

	NZ	UK	**Total**
Climate scientist	16	14	**30**
Non-climate scientist academic	7	5	**12**
Other	10	11	**22**
Total	**33** (with 7 or 21% also classed as a "sceptical voice")	**30** (with 10 or 33% also classed as a "sceptical voice")	**63**

Interviewees were asked a variety of questions related to scientific knowledge, such as the role of uncertainty, the value of scientific expertise and the legitimacy of knowledge claims emerging from climate science. Climate scientists were asked whether those critical of mainstream climate science[7] had an impact on their work, specifically on how they "do science" (i.e. scientific practice). Where possible the wording used to ask this question was that which had been previously used by the interviewee themselves, including "climate sceptics/ism", "the climate debate", or "controversy about climate change". Sceptical voices were also asked a series of questions regarding attempts to articulate their views on climate change, including their perceptions of their own impact on climate science. The data analysis comprised a multi-cycle thematic coding process in order to identify salient issues corresponding directly to the research aim, as well as to identify any other relevant themes. A mixture of coding approaches were employed, such as attribute, descriptive and values coding. Whereas the first coding cycle focused on manifest elements of the data, the second served to identify more latent or abstract components, bringing analytical meaning to the text via what Saldana calls 'themeing the data' (2009: 139). Simultaneous coding (applying two or more codes within a single datum) was frequently employed to capture the complexity of the interview discussion. Coding was conducted both within NVivo10 (following Bazeley and Jackson, 2013) and manually.

6. Results

Of those climate scientists who directly responded to the question of whether sceptical voices have had an impact on their scientific practice, i.e. how they "do science" (n=28), the majority (68%) did not perceive any such impact (Table 2). Where such impact was perceived, it predominantly focused on an increased conservatism or caution, or changes to the types or focus of research undertaken (Table 3). As Table 2 shows however, during the interview process the majority (86%) also identified other impacts that influenced their agency as scient*ists* in a more expansive manner than impact on scientific practice alone. These were impacts that either influenced them personally, or the climate science community as a whole, and were described as explicitly different to impact on practice. As NZScientist1 explains, *"they don't have an impact on how we do our science, but they have an impact on what we think about and how we provide explanations for the science, the findings that emerge"* (emphasis in original). This differentiation between impacts on "doing science" (practice) and other parts of their experience as a scientist (agency) was noted within the UK-based pilot phase and was thus explicitly investigated throughout the remaining interviews (although in the vast majority of cases it was independently identified by the interviewee themselves).

Table 2: Climate scientists' perceived impact of sceptical voices

Category of impact		NZ	UK	**Total**
Impact on scientific practice	Yes	5	4	**9**
	No	9	10	**19**
Impact on scientific agency	Yes	12	12	**24**
	No	2	2	**4**

Table 3: Descriptions of perceived impacts on scientific practice

Case study	Description of perceived impact
NZ	"I think it's trained scientists to be ultra-careful what they're saying; to be far **more conservative**" (NZScientist13)
	"…we are more **rigorous** there than we were before… that's **altered the focus** of a bit of that piece of research" (NZScientist14)
	"I was very **reluctant** or very **careful** in how I said that because I could see that this could be pulled out of context and used in a way that I, that wouldn't be consistent with what I meant... You can **choose not to show things**, or **put emphasis** in places which you may not have before" (NZScientist2)
	"I guess all it's done is **influenced the next research projects that I will do** because I want to prove these things are correct" (NZScientist4)
UK	"I think the arguments put forward by sceptics have **shaped the way that I think science should be done**, definitely" (UKScientist2)
	"Whether it was a direct or indirect consequence of *Climate Audit*, but as some kind of consequence of *Climate Audit*, **a piece of science was re-examined**" (UKScientist3)
	"You will be able to keep revisiting some of these basics and re-explaining them and that leads you to **look at the data in new ways** and suggests **possible ways for future research**" (UKScientist6)

The most commonly experienced impact related to scientific agency was that of increased caution (Table 4). Caution encompassed several distinct elements, from increased attention to scientific findings, *"for a solid year after that [Climategate] at least, Jesus we were crossing every t, dotting every i three times over for fear of getting it right. For fear of anything being wrong, being blown up out of proportion"* (NZScientist12), to the ways in which scientists communicated, particularly via email, *"I write every single email as if it is going to be read by somebody at some point in the future and they are going to be hostile to what they perceive as my intentions. So there's a chance that they will take my reputation down completely"* (UKScientist2). Communication with the media or other actors external to the scientific community was also frequently noted, with UKScientist7 stating that *"we're very, very careful about how we write press releases"*. As UKScientist2 foreshadows above, the overarching rationale underpinning increased caution was a fear of being misinterpreted, and then subsequently criticised or attacked by actors external to the scientific community on the basis of that misinterpretation. For example, UKScientist13 suggests that *"it probably does make us think more carefully about being as unambiguous and accurate as possible, and try…to avoid situations where we can be accused of misleading people"* and UKScientist11 notes that *"people are now generally afraid about saying anything off the record, maybe on the record even, just what would happen to have it misconstrued"*. Thus whereas two scientists perceived an increase in transparency as a result of sceptical voices (see Table 3), the opposite was more

commonly acknowledged, with UKScientist7 noting that this fear which results in increased caution meant that *"unfortunately…sometimes you're not quite as open as you could be"*.

Table 4: Impact identified by climate scientists on scientific agency

Type of impact	NZ	UK	**Total**
Caution	8	10	**18**
Disruption	7	4	**11**
Greater focus on communication	4	3	**7**
Defensive	1	5	**6**
Reluctance to publicly engage	2	4	**6**
Awareness of being a target	-	4	**4**
Be more critical	-	3	**3**
Certain types of sceptical voices can accelerate research	1	1	**2**
More transparency	-	2	**2**
Unwanted attention	-	2	**2**
Delay	1	-	**1**
Fewer scientists in the area	-	1	**1**
Involved in new areas of science	-	1	**1**

Notably, caution was both experienced and expressed differently by scientists in the two case study locations. In NZ, caution most often related to the communication of science and how scientists *"think very carefully both about documenting the way we do things in terms of decisions about press releases or what have you and also about thinking carefully about what we say publicly"* (NZScientist3). However, in the UK it was much more closely related to the other themes of awareness of being a target and (subsequently) being defensive. UKScientist2 provided the example of seeing a comment underneath an article in a major UK newspaper on the topic of a climate scientist contemplating suicide: *"So the very point at which I realised that it was really good to have a defence against the dark arts, was that one of the first five comments was 'I wish he had'"*. This expectation of controversy where, for example, UKScientist1 *"knew that it would end with the* Daily Mail *and* The Telegraph *attacking"* was also frequently communicated to newer scientists in the field. Junior researchers are told to expect that any comments they make publicly will result in *"people…attacking their stuff"* (UKScientist1). In addition to more extreme forms of attack, UKScientist1 also argued that that whereas it can be suggested that *"the only thing that matters to scientists is whether someone's sending you things like hate mail, but the thing that matters actually I would contend is low-*

level, the drip-drip-drip thing is very important" and suggested that this constant low-level pressure and expectation of external critique would likely be related to fewer scientists wanting to either remain in or go into climate science. These two themes were thus strongly bound up with reluctance to publicly engage, whereby *"if you beat up scientists long enough, they're just not interested in being dragged through the mud in the popular press"* (NZScientist13).

The second most prevalent theme was that of disruption. Some perceived this as a minor impact more akin to distraction, such as constant requests to respond to claims made in the media: *"you can spend your whole life doing that kind of thing"* (NZScientist1). However, UKScientist9 put forward the more commonly expressed view that *"to say it's a distraction almost trivialises it, which of course it isn't, it's very important"*. In NZ, the *"sheer time-wasting"* (NZScientist12) of scientists involved was associated with a more fundamental point about resource use in a small country. NZScientist5 succinctly summed up this perception:

> *[It is a] political tool for instance to tie up various groups of scientists so that they're always busy constantly answering a stream of questions that are not meant to be constructive in any way, they're meant to be destructive and time-wasting. That's a huge draw on resources in a very, very small place like NZ—both politically and scientifically.*

As Table 4 shows, disruption was a more prevalent theme in NZ, and was frequently related to the consequences of the NIWA-CC and the time that a particular group of scientists were required to spend on preparing NIWA's defence. The judge's ruling in favour of NIWA was deemed important not only in the NZ context, but also in terms of potential ramifications in other jurisdictions. As NZScientist16 explains, *"we heard, or we were told that once the sceptics win the case here they'll start to take them elsewhere, they'll head to Australia to take the case there. I think the Australians are happy we [NZ] won the case"*.

While the majority identified impacts in normatively negative terms, several scientists did identify personally or scientific community-wide positive impacts. The most commonly expressed of these related to communication. Scientists perceived that sceptical voices have *"really turned the climate science community to…thinking about how we communicate climate science"* (NZScientist1). In response, scientists discussed actively engaging with sceptical voices in order to *"find out what the thinking is"* (NZScientist11) or *"trying to understand where it is other people are coming from"* (UKScientist12). They also identified learning from previous experiences and paying constant attention to *"how is this going to be interpreted, how can we make sure that we get this message out smooth and clear so that someone doesn't run away*

with this sentence or that sentence" (UKScientist6). This greater focus was thus often bound up with the aforementioned theme of caution, with NZScientist6 noting that *"we tend to be quite cautious then about how we do communicate which is a shame"*. Other, less commonly expressed positive impacts included accelerating particular pieces of research in order to check claims made by sceptical voices, being more attentive to documentation, and increased transparency.

In addition to the specific types of impacts identified, another significant theme was that impact was regarded as being disproportionately borne by particular individual scientists over others. Unsurprisingly, in both NZ and the UK, individual scientists involved in high-profile events (the NIWA-CC and Climategate) were clearly identified as experiencing a larger share of impact with the ensuing ramifications *"pretty devastating for them and their careers"* (UKScientist9). These events may therefore be seen as amplifying mechanisms for controversy. In NZ, scientists who were *"in their prime in terms of their career, their ability to think, their ability to contribute…were robbed of that time and therefore NZ and the world was robbed of their contributions that could have been"* (NZScientist5). In the UK, individual scientists working in *"a big organisation like the Met Office which is high profile in terms of climate change and the whole Climategate thing"* were identified as being at *"high risk"* (UKScientist2) of being attacked. Indeed, any scientist who was recognised as having a public profile was identified as being more likely to be *"put through the wringer"* (UKScientist6). These included scientists involved with the Intergovernmental Panel on Climate Change (IPCC) or those identified as more vocally active generally in the climate change debate. In response, UKScientist8 suggested that whereas many scientists, particularly younger scientists, may be *"more or less oblivious"* to sceptical voices, others who are *"constantly bullied and tyrannised"* may respond by seeing *"it as their mission to stand up for their beliefs"* despite the fact that *"when you signed up to do science you didn't expect you'd end up in a situation like that"*. Those actively working in climate change science or policy are thus characterised as a *"beleaguered tribe who stand shoulder to shoulder"* against potential attack.

Sceptical voices themselves perceived a diverse range of impacts on climate science and scientists, with a slight majority (56%) identifying some type of impact. Indirect routes via the political process or the media were identified, such as working with politicians to ask questions of government-employed climate scientists, or the media being more critical of scientists' public communications as a result of lobbying by sceptical voices. Others identified impact mostly occurring *"at a personal level"* (UKOther4) as a result of interaction with individual scientists.

The notion of climate scientists being more transparent or reigning in more extreme projections as a result of flow-on effects from Climategate or the NIWA-CC was expressed by several sceptical voices, with UKOther2 suggesting that climate scientists are now trying *"harder to be more moderate"* and are *"now nervous about refusing data"* as a result. NZOther5 notes that impact on NIWA in particular has mostly been expressed in terms of changes to the way NIWA publicly engages, suggesting that the NIWA-CC *"has led to them [NIWA] being more circumspect about what they have to say. They're not leaving it to the newspapers now so much; they're sticking more to their science rather than advocacy, which is completely appropriate for a public servant"*. No notable variances were found between NZ and the UK as regards perceptions of impact or mechanisms through which impact was suggested to occur. It is also crucial to note that the categories of climate scientist and sceptical voice are not mutually exclusive. Interviewees who fell into both categories expressed frustration that the climate change debate has become more focused on ideological viewpoints rather than scientific merit. They also described being personally attacked, vilified, excluded and undermined from within the climate science community for their dissenting views. Further research on this population with a larger sample size to ensure anonymity is required for more rigorous and representative findings to be made.

7. Discussion

These results provide a number of implications requiring further explanation and analysis. First is a discussion of the types of impacts experienced by scientists. Table 5 collates the specific impacts identified here with those found within the existing literature to provide a conceptual framework of the ways in which controversy may influence the scientific knowledge production process, focusing on the responses of individual scientists. Encompassing scientists' agency and practice, it identifies a spectrum of potential responses from offensive engagement in terms of "rebutting" opposing claims or criticism, to defensive avoidance in terms of "removing" oneself entirely from the controversial situation. This research clearly showed impacts in terms of "reflection", where climate scientists are paying increased attention to accuracy or public communication to avoid misinterpretation; "retreat", in terms of reluctance to publicly engage; and especially "revision", where scientists are increasing cautious regarding scientific process or public communication. It is important to note however that these categories are not mutually exclusive. Indeed, the prevalence of caution and particularly its association with reluctance to publicly engage and defensiveness may be interpreted as a contributory factors in making elements of the climate science knowledge production process regarded as "nonknowledge"

(Kempner et al., 2011), classified under "removal" in Table 5. Most notably, engagement with the media is viewed as *"very dangerous"* (UKScientist8) career-wise, even though it is perceived to be *"a shame"* (NZScientist6) that scientists are unwilling to *"put their head above the parapet anymore"* (UKScientist12).[8] However, more senior scientists and those who were employed at universities (unlike those at government-funded organisations such as the Met Office or NIWA) were less likely to be concerned about engaging in such behaviours. The ability to speak freely was seen as something particularly highly valued by university-based scientists, as compared to those directly publicly-employed who are subject to *"additional constraints"* (NZScientist6) and are thus *"more pragmatic and grounded in real politik"* (NZScientist7) and cognisant of their *"pay-masters"* or "*pleasing the research council"* (UKScientist12). No clear differences were found in terms of the impact of controversy on different types of climate science undertaken; however a larger sample size may uncover further relationships of this kind.

Table 5: Scientists' potential responses to controversy

	Potential response to controversy	
Offensive engagement	Rebuttal	→ Speak out in defence of own or colleagues' work (Hilgartner, 1990) → Shift blame for shortcomings to other factors (Negru, 2013)
	Reflection	→ Increased attention to accuracy in scientific practice → Clarity in public communications to avoid misinterpretation → Increased transparency (Russell, 2010)
	Resistance	→ Actively (or passively) ignore controversy (Oliver, 2001) → Unwilling to share data (particularly when requesters are deemed troublesome or with an ulterior motive) (Swallow and Bourke, 2012) → Boundary work (Gieryn, 1983; Gieryn, 1999)
	Revision	→ Increased caution or hedging in scientific process or public communication → Adopt discourses that shape choice of scientific enquiry ("seepage") (Lewandowsky et al., 2015) → Changes to overarching professional norms (Boykoff and Boykoff, 2007)
	Retreat	→ Reduction in public engagement activities → Unwillingness to discuss personal/institutional attacks for fear of further incidents (Illman, 2005) → Change research behaviours or topics that are "forbidden" so that they become "nonknowledge" (Kempner et al., 2011)
Defensive avoidance	Removal	→ Abandon research project/research career via the "chilling effect" (Kempner, 2008)

The second major implication of this research, and perhaps the result that is particularly striking, is that while the majority of climate scientists do not consider that sceptical voices have any significant impact on scientific practice (how they "do science"), 86% did perceive impacts

on their agency as a climate scien*tist*. NZScientist1's claim that sceptical voices don't have an impact on "*how we* do *our science"* but do have an impact on *"what we think about and how we provide explanations for the science"* exemplifies the perception of the majority of scientists interviewed that the nuts and bolts of "doing" science can somehow be clearly differentiated from other elements, such as interpretation of results or interaction with the public or policymakers. It is however difficult to imagine how these may necessarily be disentangled in practice (Pickering, 2010). To take a particularly prosaic example, disruption could arguably be identified as an impact on the "doing of science" because it necessarily implies that science itself is not "being done". And whereas being more cautious and more rigorous were most commonly related to public engagement, it was certainly not restricted to those activities, with many scientists identifying increased caution throughout the scientific knowledge production process. How therefore is such a distinction able to be made? What might explain how scientists are able to separate so neatly agency and practice within "the mangle" of science? Gieryn's (1983; 1999) theory of boundary work, categorised as a form of "resistance" above, provides a way to explore this conundrum.[9] Scientific practices are, within the positivist scientific tradition, an integral part of the cognitive authority of science. Therefore, to identify the impacts experienced as affecting these practices can clearly be seen as a direct challenge to scientific legitimacy. By making a distinction between impacts on practice and on agency, scientists are thus engaging in boundary work in order to maintain the epistemic authority of science (specifically, the outputs of scientific practice) as a distinct form of knowledge production. In other words, the *very making* of the agency/practice distinction within the interview setting as the scientist responds to questions regarding perceptions of impact *is in itself* a performance of boundary work.[10] Framing impacts in terms of scientific agency is arguably more acceptable as it does not impinge to the same degree upon the legitimacy of the claims emerging from scientific practice. Moreover, the types of impacts that were identified as influencing scientists' agency are largely also able to be formulated according to the notion of the Mertonian ideal. For example, being cautious is a laudable trait as it evokes ideas of preciseness and replicability. This performance of boundary work is important because it provides scientists with a way of coping with the *"discursive fluidity"* (NZAcademic3) and (possibly unexpected) politicisation of the scientific environment evident within controversial situations (Brown, 2015). For those scientists who identified impacts such as caution as influencing their scientific practice (i.e. they agreed that sceptical voices influenced how they "did" science, shown in Table 3), it thus also seems possible that that they perceived less of a need to engage in this performative boundary work. Further work involving a larger sample size to determine the variables (such as level of seniority, type of science undertaken or level of engagement with the public or with controversial events) that may be relevant is therefore an important extension of this work.

A third implication of this research is that sceptical voices operating outside the formal epistemic community of science were generally regarded as unable to exert influence until the final product (e.g. a journal article) is made public. However, once this protected "black box" which contains the work of "doing science" has been opened, sceptical voices were then seen to engage in ex-post critiques (which may cycle back through nearly all the stages of the scientific knowledge production process), querying each micro-decision made by individual scientists in an effort to challenge the science itself or the policy implications of potentially unwelcome scientific findings. Thus, if sceptical voices are making scientists *"much more careful about anything we publish, okay, where are the error bars, where's the statistical significance"* (UKScientist9) it is also likely that these new forms of checking and double-checking may become entangled with the epistemological norms of the discipline itself, and filter back into the ways in which scientists expect themselves and others to behave, particularly in terms of their role as scientific experts. Moreover, if climate scientists are fearful of being attacked and/or misinterpreted, it is also unsurprising that, for example, institutions such as the IPCC are increasingly *"incredibly conservative about what it's said because it's been so terrified not to undermine itself by saying things that can then be shown to be wrong"* (UKScientist8). This echoes Jasper and Poulson's (1993: 642) finding that once an organisation is 'spotlighted by protest', its reputation for credibility and competence are likely to be particularly emphasised by its opponents as a mechanism to challenge legitimacy.

Fourth and finally, the significant events of Climategate and the NIWA-CC not only had considerable impact on scientists' agency and practice, but also on determinations of expertise and the trust placed in climate scientists and, in turn, climate science as a whole. In terms of the former, the NIWA-CC was particularly relevant not only as regards the legitimacy of scientific data and how/who by that legitimacy may be determined, but also in terms of whose expertise is deemed adequately relevant to both produce and criticise knowledge. The presiding judge, Justice Venning, remarked several times in his judgement that the NZCSET plaintiffs did not hold comparable expertise to that of the NIWA scientists: 'He has no applicable qualifications. His interest in the area does not sufficiently qualify him as an expert' (NZCSET v NIWA [2012] NZHC 2297: paragraph 51). Justice Venning argued throughout his decision that the court could not, and should not resolve a scientific debate. Particularly, he contended that the court 'should not seek to determine or resolve scientific questions demanding the evaluation of contentious expert opinion' (NZCSET v NIWA [2012] NZHC 2297: paragraph 48) and in his awarding of costs to the defendant, that the 'issue of whether there is global warming and climate change is a

scientific issue, not suitable for determination by a Court' (NZCSET v NIWA [2012] NZHC 3560: paragraph 46). However, in a legal review of the case, Hardcastle (2014: 292) argues that 'the decision offers insufficient protection for scientists and scientific research' because it has, in essence, provided precedent for the High Court of NZ to review research compiled by CRIs. Hardcastle (2014: 291) contends that CRIs' decisions should only be reviewed in cases of 'fraud, corruption or bad faith', a pre-existing standard established in a 1994 Privy Council determination. She also suggests that research, especially if findings are controversial, may either stagnate or be less likely to be published if scientists are fearful of judicial review. Importantly, criticisms of individual scientists involved in these key events were also perceived to contribute to a reduction in the public's value of, or trust in, science. NZScientist12 argues that not only did the controversy surrounding the NIWA-CC mean that sceptical voices were *"driving the show"*, but that it also required scientists to *"rebuild faith and trust in the public's mind…[due to] that doubt and those seeds that went into Joe Blogg's mind"*. Climategate was also perceived as *"damaging to climate science because it undermined trust"* which is what *"science relies on"* (UKScientist5) in terms of a public licence to operate. Recognition that those who are publicly visible are those who are more likely to be attacked means it is entirely possible, if not likely, that this would result in less representation from scientists in the public arena. Even if climate scientists perceive it to be part of their "duty" as a scientist to be publicly vocal (Sharman and Howarth, 2015), it is possible that sustained attack, combined with certain scientists' perceptions that they are not able to speak freely given funding or employment status, may limit such activity in practice.

8. Conclusion

This research investigated the impact of controversy on the production of scientific knowledge, focusing specifically on impact experienced by individual climate scientists in NZ and the UK. The majority of climate scientists (68%) did not perceive that sceptical voices had an impact on scientific practice; however 86% did identify impact on scientific agency. The predominant type of agency-related impact was increased caution, followed by disruption, a greater focus on communication, defensiveness and a reluctance to publicly engage. Caution was experienced differently within the two case study locations, with implications for the communication of science most prevalent in NZ, and associated with being a target for attack and (subsequently) being defensive in the UK. A very slight majority of sceptical voices (56%) considered that they personally had an impact on climate science/scientists either indirectly through political or media avenues, or via more direct interaction with individual scientists. A conceptual

framework of potential response to controversy was provided, ranging from "rebuttal" at the end of offensive engagement to "removal" at the end of defensive avoidance.

Two wider conclusions emerge from this research, with the first related to the distinction between impacts on agency and practice as a form of boundary work. Gieryn suggests that boundary work would be expected in situations where credibility is contested, as the epistemic authority gained by boundary work only exists 'to the extent that it is claimed by some people…but denied to others' (1999: 14). This research extends his argument by contending that boundary work is a more *active* and *explicit* process under conditions of public scientific controversy, as scientists work to ensure the independence and unassailability of their cognitive authority in contested domains. Specifically, scientists' ability or need to explicitly differentiate between impacts on agency and practice within Pickering's (1992; 1993; 2010) "mangle" may therefore be understood as a function of controversy, with the greater the impact of controversy, the less fluid and contingent the boundary between the two. It is thus a coping strategy which protects the dominant paradigm in which one operates as able to provide an accurate or representative truth about the world, rather than just a series of contestable knowledge claims. Delineating who is able to "do science" is thus also likely to be more important in controversial situations as a form of strategic defence. As a result of outside attacks, scientists become protective as to their ability to carry out the constituent activities of science unencumbered. While there was some recognition of exceptions to the rule, such as *"people who do not have PhDs in related fields of science who have a history of doing high, high quality work"* (NZScientist5), markers of expertise such as publishing in the peer-reviewed literature were explicitly argued as critical in being able to identify an individual as a credible voice on climate science. This type of boundary work in terms of attributing legitimacy via pre-existing markers of expertise is not unique to controversial situations (Lamont and Molnár, 2002). However, it seems unsurprising that factors such as entry requirements to conduct scientific practice may be accorded greater importance under conditions of controversy. Nonetheless, further investigation applying both the conceptual framework shown in Table 5 and testing the above relationship between impact of controversy and fluidity of the boundary between scientific agency and practice in other case study locations and areas of scientific enquiry is recommended.

Secondly, the predominant impacts experienced, notably increasing caution, perceptions of being under attack and defensiveness, have important implications for epistemological norms and the social value of science. As indicated above, certain climate scientists perceived

normatively positive consequences arising from interaction with sceptical voices, including increased attention to detail and rigour in scientific enquiry, or trends towards greater transparency. "Reflection" is a particularly important category of potential response as public scrutiny may indeed improve the scientific process by making it more publicly accessible or critically self-reflexive. However, a greater number suggested that there was significant reluctance to directly engage with the public or the media for fear of being misconstrued. In particular, being personally attacked, or seeing other, especially well-known scientists attacked, can result in researchers being reluctant to communicate research findings beyond academia or being dissuaded from participating in public fora. If wider communication of results or public engagement becomes regarded as overly risky, a potential consequence is that it may no longer be regarded as a "normal" part of the activities of a scientist (whilst recognising that not all scientists have previously, or would desire to, directly publicly engage). This could lead to increased outsourcing of communication activities to third parties (such as science communication specialists) rather than forming part of (willing) scientists' practices, breaking the direct relationship between scientists and the public that is understood to contribute to public perceptions of the social value of science (Chavis et al., 1983; O'Brien, 2013). Consequences for effective public decision-making may also be experienced, especially if highly publicly controversial research is suppressed or dampened down (e.g. extreme model projections). However, further research is required to provide more concrete examples of the impact of controversy on the policy decision-making process, particularly as regards specific contexts and settings.

9. Notes

1. The role of non-human actors as contributors to the scientific knowledge production process is acknowledged (Latour, 1996) but is not the focus of this research.
2. In 2014, 84% of the UK public agreed that climate change is either partly or mainly anthropogenic (Capstick et al., 2015). In 2009, 59.5% of New Zealanders agreed that climate change was caused by humans (Sibley and Kurz, 2013).
3. This paper follows Painter (2011) and Howarth and Sharman (2015) by using "sceptical voice" to move away from the problematic labelling constructs evident in the climate debate. The emphasis on the idea of a "voice" re-focuses on the human (the "who" someone is, rather than the "what") whilst also recognising the need for a pragmatic descriptor.
4. "Climategate" is the colloquial term for the release without authorisation of over 1,000 emails and documents from the University of East Anglia in 2009 on the eve of the United

Nation's Framework Convention on Climate Change's 15th Conference of the Parties in Copenhagen.

5. CRIs are registered companies wholly owned by the Crown that carry out scientific research for the benefit of New Zealand.
6. The GWPF is a charity established in 2009 aimed at advancing public understanding about climate change, including potential policy responses. Its chairman, Nigel Lawson, is highly visible in the news media as a sceptical voice (Grundmann and Scott, 2014). In 2014, the GWPF divided in two, adding a campaigning arm (the Global Warming Policy Forum) in response to a Charity Commission investigation finding that its activities were not corresponding to its main purpose as an educational charity (Charity Commission, 2014). Research for this paper occurred prior to this split so all references to the GWPF are to the foundation, not the forum.
7. Mainstream climate science refers to the scientific position on climate change as expressed in the Intergovernmental Panel on Climate Change (IPCC) fourth and fifth assessment reports (2007; 2013).
8. The notion of a parapet or protective walls was interesting, principally in terms of defensiveness and a separation between science and society, and was explicitly referred to 15 times in 12 separate interviews across all interviewee categories.
9. See also Jasanoff (1987) and Ramírez-i-Ollé (2015) for other examples of the use of boundary work in related contexts.
10. It is critical to acknowledge the performative sense-making process that can occur during qualitative research interviews (Lucius-Hoene and Deppermann, 2000; Denzin, 2001; Heiskanen, 2005). The boundary work of making the distinction between agency and practice seen here may be different under different research conditions such as ethnographic research, or survey-based methods.

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