

# 1 **Resilient science: The civic epistemology of Disaster Risk Reduction**

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## 5 **Abstract**

6 In this paper, we use science studies to elucidate the nature of advisory science in the context of  
7 disasters, particularly those involving geophysical hazards. We argue that there are some key  
8 differences between disaster advisory science and the issues that are most discussed in Science  
9 Studies: they are both time- and space- specific and they constitute major social, economic, and  
10 scientific shocks. We suggest that disasters require flexible advisory structures that maximise the co-  
11 production of science and social order, and present a framework for this. We argue that the aim of  
12 increasing resilience to natural hazards requires that sociology of scientific knowledge play a part in  
13 the application of scientific advice: disaster studies has focussed on the reduction of vulnerability as  
14 a reaction against technical-rational models of scientific advice, but in doing so has restricted the  
15 potential role of the social sciences in the framing of scientific advice and expertise.

## 16 **Introduction**

17 In November 2012, an Italian court found six scientists and a local official guilty of manslaughter for  
18 misinforming the public about seismic risk in L'Aquila, where a devastating earthquake occurred on  
19 6<sup>th</sup> April, 2009. This verdict was received with much concern in the scientific community, with many  
20 organisations condemning it as detrimental to the willingness of scientists to act as policy advisors –  
21 an increasingly important part of their work (e.g. Marzocchi, 2012). The verdict reflects on a

22 breakdown in the risk communication process – perhaps, as some have alleged, because of political  
23 interference in the advice that was given (Hall, 2011). Other shortcomings appear to have been a  
24 lack of transparency, a failure by the scientists and officials to regard the public as an intelligent  
25 entity, and the absence of adequate governance structures with clear remits (see Alexander, 2010  
26 and 2013a for detailed critiques of the disaster management policies in Italy).

27 There are also important lessons from L’Aquila regarding the positionality of scientists in disasters.  
28 This is particularly relevant to geophysical hazards (defined here as earthquakes and volcanic  
29 eruptions), since the level of uncertainty involved in the management of their associated impacts is  
30 very high and there is heavy dependence on scientific advice, sometimes over periods of decades  
31 (e.g. Donovan et al., 2013). By one estimate, the probability that the small earthquakes preceding  
32 the L’Aquila earthquake were foreshocks (i.e. would be followed by a larger earthquake) was less  
33 than one percent (Marzocchi, 2012). Such events were discussed in the UK Government’s Blackett  
34 Review of High Impact Low Probability Risks (Government Office for Science, 2011), which placed  
35 strong emphasis on the involvement of external experts in the policy process. In extreme events,  
36 however, advisory committees may be formed ad hoc (e.g. Donovan et al., 2013; Newhall and  
37 Punongbayan, 1996; Aspinall et al., 2002), and their remit and responsibilities may not be well  
38 defined. Furthermore, as demonstrated in Italy, the legal responsibilities and accountabilities of  
39 scientists are problematised (e.g. Marzocchi, 2012; Aspinall, 2011). While scientists have generally  
40 condemned the verdict, there are also disagreements about “best practice” both within seismic  
41 hazard assessment (notably between advocates of probabilistic analysis and those who prefer  
42 deterministic methods) and in the act of providing scientific advice.

43 These debates highlight a critical issue that is frequently overlooked or understated in the disaster  
44 studies literature: the diverse mechanisms, institutions and epistemologies involved in the provision  
45 of scientific advice and its integration with local knowledge, particularly in the context of high  
46 scientific and social uncertainties, can exacerbate disasters if they are not clear from the outset. The

47 Italian case has highlighted the vulnerability of experts when both uncertainty and the stakes are  
48 high. It has demonstrated the pivotal nature of the relationships between expert advisors and social  
49 and political structures in emergencies and demonstrated that these can be significantly disordered  
50 and reordered by the activity of the Earth, with costly social consequences. This can extend the  
51 recovery time post-disaster, and understanding these relationships may aid future disaster risk  
52 reduction.

53 The murky epistemological status of advisory science has been addressed in the Science Studies  
54 literature in the context of the co-production of knowledge by science and society (e.g. Jasanoff,  
55 2004; Doubleday, 2007). The co-production idiom is able to negotiate between the social  
56 construction of science and the realist view of science, by examining the ways in which knowledge  
57 production is linked to its context. Co-production has local echoes; it is closely tied into grounded  
58 practice and governance systems (Jasanoff, 2004, 2005). In response to risks, particularly low  
59 probability, high impact risks, the process of knowledge production changes as a result of sudden  
60 societal need, requiring intense collaboration between scientists and society (both political officials  
61 and the public). This is one of the key challenges in managing sudden-onset natural crises such as  
62 earthquakes and volcanic eruptions, and depends on institutional structures, relationships between  
63 different groups and the development of the crisis as defined by the earth system.

64 Accepting that the natural and the social world are produced together requires new approaches to  
65 the understanding of “knowledge”. In her 2005 work, *Designs on Nature* (Jasanoff, 2005), Sheila  
66 Jasanoff presents the concept of “civic epistemology”:

67 Civic epistemology refers to the institutionalised practices by which members of a given society test and  
68 deploy knowledge claims used as a basis for making collective choices...these collective knowledge-ways ... are  
69 distinctive, systematic, often institutionalised, and articulated through practice rather than in formal rules  
70 (p255).

71 Jasanoff presents a framework through which different cultural knowledge-ways can be examined  
72 and analysed, using examples from biotechnological discourses in the UK, US and Germany. She  
73 analyses six “dimensions” of civic epistemology – styles of public knowledge-making; public  
74 accountability; public demonstration; objectivity registers; expertise; and the visibility of expert  
75 bodies. Each of these dimensions reflects some aspect of the culturally derived epistemic basis for  
76 the social application of scientific knowledge. These tests and evaluations of knowledge claims  
77 intensify when a new type of threat faces a population imminently. In this situation, pressure on  
78 scientific advisors can be intense, and attempts may be made to promote a “linear model” approach  
79 to scientific advice (e.g. Marzocchi et al., 2012), in which the role of scientists is, in theory, clearly  
80 delineated. As sociologists of scientific knowledge have shown, however, this “boundary work”  
81 (Gieryn, 1983) is not straightforward, because the distinctions between science and non-science are  
82 not obvious – especially in policy contexts. For example, scientists in policy contexts have to make  
83 judgements about issues that would not normally concern them in a laboratory setting. They have to  
84 take incomplete and uncertain knowledge and produce a coherent answer to a socially relevant –  
85 not necessarily scientific – question. In a crisis, this is affected by pressures that are external to  
86 scientific process – such as the need to make evacuation decisions. The testing of knowledge claims  
87 under these circumstances are intensified prior to any event that may occur in the natural system,  
88 and may have considerable influence over subsequent responses to scientific advice. In a volcanic or  
89 seismic crisis, the timescales usually available to scientists for their own testing of knowledge are  
90 much shorter, so the uncertainty is very high, but at the same time, the advice is desperately needed  
91 by authorities. In this paper, we present a new framework, based on co-production, for approaching  
92 the civic epistemology of disasters. This analysis is based on review of the scholarly literature, and on  
93 scientific and policy reports where specified.

94 Initially, we examine the relationship between resilience and scientific advice, drawing on the  
95 disasters literature. We then summarise the key tensions that dominate when scientists are asked to

96 provide advice under uncertainty, as they seek to construct authority around incomplete knowledge.  
97 We argue that scientific advice in environmental crises can, in some cases, be conceptualised as a  
98 “civic epistemological rupture”: an event that changes the position and relationship between  
99 scientific advisory practice and the public in a specific time and place. In particular, we suggest that  
100 apparent obstacles to “pure” science in the process of risk assessment and management may be  
101 overcome by structured, civic epistemological framings and aid the co-production of social order in  
102 the disaster management process (drawing on the work of Sheila Jasanoff, 2004, 2005,2010). Studies  
103 have shown that scientific advice in volcanic crises, for example, is subject to and penetrated by  
104 similar social, political and economic considerations as scientific advice in other contexts (Donovan  
105 and Oppenheimer, 2014, 2015; Fearnley, 2013; see also for example Owens, 2005; Jasanoff, 2005). It  
106 is, however, more time-critical in environmental crises than it is in relation to biotechnology or  
107 nuclear technology – and the timescale is set by the natural environment. For effective reduction of  
108 disaster impacts, consideration must be paid to the institutional and epistemological framings of  
109 expert advice, as well as to the more common issues of public education and planning. We present a  
110 framework that aims to contribute towards a civic epistemology of disaster science.

## 111 **Scientific advice and increasing resilience: Why do we need a** 112 **framework?**

113 Disasters have been framed as “windows of opportunity” (e.g. Birkmann et al., 2010) and “catalysts”  
114 (e.g. Kreps, 1998). White (1945) noted that while natural hazards may be “acts of God”, losses as a  
115 result are “largely acts of man”. Hewitt (1997) identified the dangers of depending on scientific and  
116 technical approaches to disaster management, focusing instead on disasters as social processes and  
117 the reduction of social vulnerability. This approach has dominated disasters literature in recent  
118 decades (e.g. Cutter 2003; Wisner et al., 2004, 2011; Smith, 2001; Hewitt, 2013): the concept of a  
119 “natural disaster” is a contradiction in terms. Recent literature has also adopted the ecological  
120 concept of “resilience” as a means of understanding the ways in which societies deal with disasters

121 (e.g. Adger et al., 2005; Paton, 2006). While critical, the focus on community resilience and  
122 vulnerability has arguably coexisted with *a neglect of the role and nature of scientific advice in*  
123 *disaster management* – and this is the topic we seek to address in this paper. In the case of seismic  
124 and volcanic risk assessment, the importance and difficulties – shown at L’Aquila – of applying  
125 world-class science to the problems should not be underestimated (Tilling, 2008; Gaillard and  
126 Mercer, 2013), even though it is a small part of the overall picture of disaster risk reduction (DRR).

127 The UN ISDR defines resilience as follows:

128 ‘The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to  
129 and recover from the effects of a hazard in a timely and efficient manner, including through the  
130 preservation and restoration of its essential basic structures and functions.’

131 Resilience in this definition is thus closely tied to adequate governance and resources, and to the  
132 preparedness of local people (Paton, 2006; Paton and Johnston, 2006). However, the use of the term  
133 has become so widespread that its meanings are increasingly difficult to reconcile, particularly when  
134 combined with other Disaster Risk Reduction terms (such as vulnerability, capacity and exposure;  
135 e.g. Manyena, 2006; Alexander, 2013b, Lewis and Kelman 2010; see also Adger, 2006 and Gallopin,  
136 2006). Alexander (2013b) suggests that the term has the potential to remain useful as long as its  
137 limitations are recognised – particularly when it is applied to complex social systems. Resilience can  
138 be used to theorise the process of disaster risk reduction, but it cannot describe it in its entirety. It  
139 offers insight into the processes of recovery and the factors on which they depend. The resilience of  
140 a society to a hazard depends on the pre-disaster infrastructure and on adaptive capacity (e.g.  
141 Pelling and High, 2005; Gaillard, 2007), and on the nature of the hazard and its impacts. The ability of  
142 critical systems to adapt to the changing circumstances can have a significant impact on the recovery  
143 process (e.g. Gaillard, 2007; Handmer, 2003). This includes the ease with which expert advice can be  
144 located and integrated into disaster risk management.

145 Wisner et al (2012) and Gaillard and Mercer (2013) developed a road map for disaster risk reduction.  
146 They identified three strands of DRR: risk assessment, dialogue and action. In each of these, the  
147 integration of local and scientific knowledges was highlighted. In the case of extreme hazards,  
148 however, where uncertainty is high, knowledge claims can become contested very rapidly and this  
149 whole process changes the nature of knowledge generation and management in a local, social  
150 context. There may be interaction between the risk assessment process and the processes of  
151 dialogue and even action within the helpful scheme of Gaillard and Mercer (2013): risk management  
152 is not in practice a linear progression. Social and political complexities affect scientific knowledge  
153 production, especially under uncertainty. While it is critical that scientists do interact with local  
154 communities prior to hazard realisation to maximise the integration of local and scientific  
155 knowledges, it is also important to note that the role of science in disaster management may also  
156 involve the negotiation of very high levels of uncertainty in the risk assessment process, alongside an  
157 anticipation of public response. This requires a consideration of epistemological issues that arise in  
158 risk assessment and in its integration with policy – something that is significantly aided by taking a  
159 co-production approach. Stakeholders may demand information on the evidence behind policies, for  
160 example, as was witnessed in the 2010 ash crisis in Europe when airlines questioned the necessity of  
161 airspace restrictions (e.g. Donovan and Oppenheimer, 2011). These issues involved uncertainty  
162 concerning scientific models and observations, as well as expert opinion. The time-critical nature of  
163 these processes during a crisis necessitates careful planning on the part of scientists and  
164 practitioners. In the next section, we discuss some insights into the science-policy process that have  
165 been made in other fields that are less time-dependent than our context. In doing so, we draw on  
166 the Science Studies literature and on perspectives from the philosophy of science.

## 167 **Civic epistemological ruptures: A framework for DRR**

168 Scholars in Science Studies have examined the interface between science and policy in a range of  
169 fields (e.g. Collins and Evans, 2007; Jasanoff, 2004, 2005, 2007; Nowotny et al., 2003; Brown, 2009;

170 Fischer, 2010). Geographers of science have also discussed science and policy, particularly in relation  
171 to environmental knowledge controversies (e.g. Lane et al., 2011; Whatmore, 2009) and field  
172 stations (Powell, 2007). The combination of disaster studies and Science Studies enables an  
173 interrogation of the practice of science in particular places at particular times, examining its social  
174 context, methods and identity. It can contribute to policy making through the identification of the  
175 themes and patterns that emerge from such studies and that may provide insights for future  
176 planning. In the context of disaster research, this is critical in the building of resilience to manage  
177 future events. Risks from natural hazards are spatially constructed (Hewitt, 1997, 2013; November,  
178 2004, 2008; Wisner et al., 2004; Pelling and High, 2005; Pelling and Dill, 2010), and the interaction  
179 between physical and human factors is complex: risk both transforms and is transformed by spaces  
180 (November, 2008). Indeed, attempts to quantify and assess risks do themselves have an impact on  
181 the way that risk is framed in a social context (e.g. Haynes et al., 2008), and social context can have  
182 an impact on the ways in which risk assessment is carried out, as scientists try to anticipate the  
183 critical social questions. In individual cases, the importance of the experience, judgement and  
184 political awareness of scientists in the advisory process has been demonstrated repeatedly (e.g. Hall,  
185 2011; Haynes et al., 2008). The growing reliance on subjective risk assessment methodologies such  
186 as expert elicitation demonstrate the liminal nature of the policy interface – and can present  
187 challenges for the philosophies of individual scientists (e.g. Castanos and Lomnitz, 2002; Aspinall,  
188 2012; Donovan et al., 2012b,c). The concept of boundary work is important here (Gieryn, 1983).  
189 Scientists have been observed to attempt to delineate their work from that of policymakers using a  
190 range of tools, including the rhetoric of objectivity and the use of quantitative assessments. In  
191 practice, however, the “boundary” between science and policy is leaky (Owens, 2005; Owens et al  
192 2006; Eden et al., 2006; Lovbrand, 2007; Donovan and Oppenheimer, 2014

193 Gaston Bachelard argued that “science is the aesthetic of the intellect” (1938:21), and that many  
194 aspects of the human mind conspire to taint the pursuit of “objective” knowledge. He refers to these



195 as “epistemological obstacles” – these hinder the breakthroughs in scientific discovery that are  
196 referred to as “epistemological ruptures”; and “epistemological acts” are processes that aid such  
197 ruptures<sup>1</sup> (see also Althusser, 1969 and Foucault, 1969, for other uses of these terms). He offers a  
198 psychoanalytical approach to understanding objective knowledge, noting that the primary obstacle  
199 to the progression of scientific thought is common sense. At the crux of these discussions is a  
200 contestation of the relationship between subjectivity and objectivity: it is the humanity, feelings and  
201 impressions of the individual that present an obstacle to scientific progression (Bachelard, 1938). In  
202 contrast, scientific advice frequently depends upon such impressions: scientists’ judgements are  
203 based on their expertise but are inevitably subjective and may also depend on context (social and  
204 scientific). This liminal science may be uncomfortable and result in those participating being self-  
205 selecting. It may challenge accepted scientific methods and be forced to apply untested techniques  
206 in the service of social need. However, this can also lead to breakthroughs both in the practice of  
207 science and in its societal role (e.g. Donovan et al., 2012a; Sparks, 2007). Aspects of the psyche that  
208 Bachelard considered to be a hindrance to the progression of science (“epistemological obstacles”)  
209 *may actually help the progression of scientific advisory practice*. For example, recent work has  
210 emphasised the importance of embracing subjectivity in science (O’Brien, 2010; Curtis, 2012). From  
211 a different perspective, the widely used method of “scenario planning” (Ringland and Schwartz,  
212 1998; Alexander, 2000; Lindgren and Bandhold, 2002) requires a level of expert imagination –  
213 something also considered an obstacle by Bachelard.

214 Reading Bachelard through the lens of the last thirty years of research, we could surmise that  
215 understanding the relationship between the self – complete with impressions, imaginings and  
216 interpretations – and the “object” in nature is at the heart of negotiating uncertainty in scientific  
217 advice. This is the foundation of the co-production idiom, and hints at its usefulness in bringing  
218 together the social and physical sciences. It is the expert self that has to straddle the uncertainty-

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<sup>1</sup> Volcanic eruptions can, therefore, be epistemological acts through the advances that come about through the rapid acquisition of volcanological knowledge that results from them (e.g. Baxter, 2008; Donovan et al., 2013).

219 ridden boundary between knowledge and advice – a social experience that requires social scientific  
220 analysis. Experts have to interact both with peers and with “lay people” – including local officials and  
221 populations. Bachelard viewed epistemological ruptures as positive: they advance human learning.  
222 We suggest that extreme events such as volcanic eruptions, large earthquakes and other high  
223 magnitude hazards can produce *civic* epistemological ruptures: they change the course of knowledge  
224 production at the science-society interface, through shared experience and learning. If this occurs  
225 efficiently, it will facilitate resilience as a part of adaptive capacity. If it fails and information is  
226 disputed, unclear or unavailable, response to the hazard will be similarly delayed and confused as  
227 expertise is assembled ad hoc.

228 The trial of six seismologists and a public official in Italy can be read as a civic epistemological  
229 rupture: it has shaken the ways in which scientists think about providing advice and it has brought  
230 the relationships between scientists and society in a particular place to light. In the next section, we  
231 discuss the events in more detail, focussing particularly on the wider scientific response, in which  
232 senior scientists and scientific institutions reactively strongly and quickly to a complex situation in a  
233 way that was itself not at all ‘scientific’ (Alexander, 2014). We show that many of the debates about  
234 L’Aquila in the broader scientific community revolve around the establishment of authority – the  
235 authority of “science”, and also of particular people who practise it. This attempt to establish  
236 authority works against science because it resists the ideas of co-production and civic epistemology.

## 237 **Events at L’Aquila and the construction of authority**

238 The trial, sentencing and subsequent acquittal of six seismologists on the Major Risks Commission in  
239 L’Aquila provoked a very wide range of responses. Scientific institutions condemned the verdict.  
240 Some examples:  
241 “It is thus incorrect to assume that the L’Aquila earthquake should have been predicted. The charges  
242 may also harm international efforts to understand natural disasters and mitigate associated risk,

243 because risk of litigation will discourage scientists and officials from advising their government or  
244 even working in the field of seismology and seismic risk assessment.” American Geophysical Union  
245 (AGU)

246 “They are clearly all eminent scientists with many years of experience in their expert fields, not  
247 novices. To charge these scientists with criminal neglect is unconscionable. The scientists did not  
248 cause the earthquakes, they could not prevent them, nor could they predict them, so how could  
249 they be guilty of manslaughter? This is a farce and they have been made scapegoats.” International  
250 Association of Volcanology and Chemistry of the Earth’s Interior (IAVCEI)

251 "We are deeply concerned. It's not just seismology which has been put on trial but all science,"  
252 Charlotte, Krawczyk, Seismology division at the European Geosciences Union (EGU)

253 “This trial has raised huge concerns ... Because here you have a number of scientists who are simply  
254 doing their job being accused of criminal manslaughter”. Tom Jordan, Southern California  
255 Earthquake Center (SCEC)

256 “The charges against these scientists are both unfair and naive. The basis for those indictments  
257 appears to be that the scientists failed to alert the population of L’Aquila of an impending  
258 earthquake. However, there is no way they could have done that credibly.” American Association for  
259 the Advancement of Science (AAAS)

260 “When serving on high level advisory panels for governments and authorities, scientists have the  
261 duty to provide the state of knowledge in a comprehensive and unbiased fashion, to enable  
262 authorities to take the required mitigation actions. This cannot be achieved under the threat of  
263 public prosecution. A negative impact of this trial and sentence will be to make scientists reluctant to  
264 serve on risk advisory commissions or express expert opinions. “ International Association of  
265 Seismology and Physics of the Earth’s Interior (IASPEI)

266 These comments hold within them several latent views about scientific advice: that reputation  
267 (“eminent scientists”) is a major source of authority; that this specific incident is a trial of “all  
268 science”; that scientists on advisory panels are “unbiased”; and that science is beyond reproach.  
269 These reactions betray a positivist view of scientific knowledge and authority, much like that  
270 championed by Bachelard. The trial was widely misread as a trial of science, as has been noted by  
271 several commentators (e.g. Hall, 2011; Alexander, 2014; Yeo, 2014). The problem was that the public  
272 were reassured by a local official (also sentenced to jail time, though this has since been reduced at  
273 appeal) that there was a “favourable situation” because the small earthquakes were releasing the  
274 stress on the faultline. This was presented as the scientific viewpoint. On 31<sup>st</sup> March 2009, a meeting  
275 of the Major Risks Commission was convened, and evidence emerged at the trial to suggest that the  
276 reason that the committee had met was that public officials wanted to calm the public down  
277 following the small earthquakes and the claims, made by a technical officer (not a seismologist) that  
278 radon gas emissions suggested there would be a major earthquake. The minutes of the meeting,  
279 published by L’Espresso magazine, state:

280 Alla riunione partecipano le massimo autorità scientifiche del settore sismico, in grado di fornire il quadro più  
281 aggiornato e affidabile di quanto sta accadendo.

282 (The greatest scientific authorities in the field of seismology are participating in the meeting, in order to  
283 provide the most up-to-date and reliable picture of what is happening.)

284 Thus, one of the issues that underlies the case is the construction of authority: senior scientists held  
285 in esteem by the state were asked to silence the concerns of an “amateur” – and this has continued  
286 in the aftermath (e.g. see Alexander, 2015). It is interesting to note that subsequent responses from  
287 scientists have cautioned that the case may itself lead to scientific advice being the realm of  
288 “mavericks and charlatans” who are willing to take the risk of prosecution (see Cartlidge, 2012). The  
289 responses to the verdict are also symptomatic of a defensive science that reinforces the perceived  
290 division between “science” and “non-science” as a source of authority. They were also, interestingly,

291 almost entirely ignorant of the nuances of the local context (as described eloquently by Alexander,  
 292 2014): the scientists were associated with the political ‘caste’, which is increasingly mistrusted by the  
 293 population. This also emerged in the responses of other Italian scientists to the reaction from the  
 294 wider scientific community. One senior scientist wrote, in an email to a global list for volcanology  
 295 (“Volcanonet”) that “scientists are only able to be truly independent if they have been assigned  
 296 positions purely on the basis of their scientific expertise and merit. However, if such positions are  
 297 acquired based on personal bias, relationships or "association" and not on scientific competence, it  
 298 is clear that the scientist loses their autonomy.” There were clearly political problems within the  
 299 Italian scientific community as well as between it and other groups. This paper is not concerned with  
 300 the details of the indictments or the debates that have followed (e.g. Alexander, 2014, 2015;  
 301 Gabrielli and Di Bucci, 2015; Aspinall, 2011; Marzocchi, 2012). Instead, we pick up on a number of  
 302 themes that are distilled from this example and from others in order to suggest a way forward for  
 303 studies of scientific advice in disasters. These include the ways in which scientists involved in advice  
 304 are identified, the representation of uncertainty in reporting, the social context and the governance  
 305 structures involved.

306 Table 1 presents a brief timeline of events at L’Aquila.

Date	Event
<b>October 2008</b>	Earthquake sequence starts.
<b>March 2009</b>	Giampaolo Giuliani measures elevated levels of radon gas and warns the authorities
<b>31<sup>st</sup> March 2009 18.30</b>	Major Risks Commission meets. Some key points made by scientists: <ul style="list-style-type: none"> <li>- a sequence of earthquakes does not necessarily constitute a precursor to a larger event</li> </ul>

	<ul style="list-style-type: none"> <li>- it is extremely difficult to forecast earthquakes</li> <li>- the only way to prepare for earthquakes is to focus on improving buildings</li> </ul>
<b>31<sup>st</sup> March 2009 (time unknown)</b>	De Bernadinis, a public official on the Major Risk Commission, reassured the public that there was no danger and, prompted by a journalist, recommended his favourite wine.
<b>6 April 2009</b>	Earthquake occurs, killing 309 people
<b>3<sup>rd</sup> June 2010</b>	Indictments issued against six scientists and a local official
<b>25 May 2011</b>	Prosecution commences
<b>October 2012</b>	Six scientists and De Bernadinis convicted of manslaughter and sentenced to six years in prison
<b>November 2014</b>	Convictions of six scientists overturned; De Bernadinis' sentence reduced to two years.

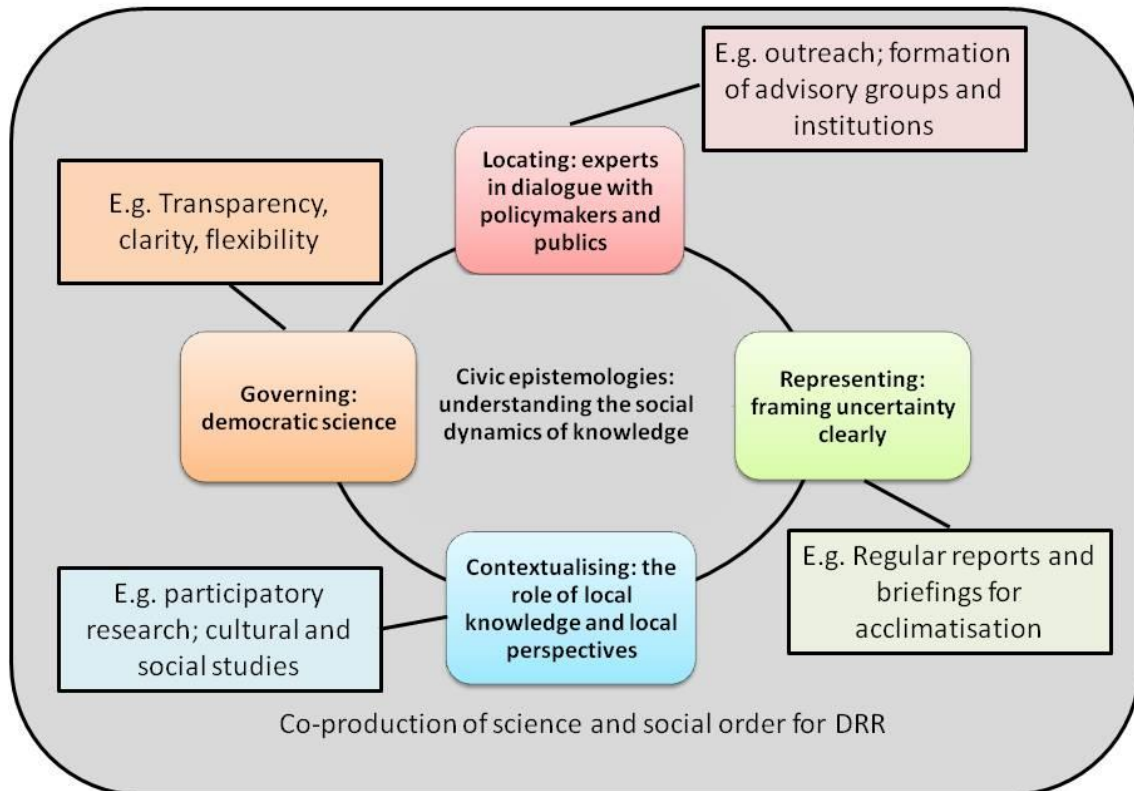
307 Table 1. Simplified timeline of the L'Aquila trial. Sources: L'Espresso (minutes of the meeting on 31  
308 March); Alexander, 2014, 2015; Gabrielli and Di Bucci, 2015; Cartlidge, 2011; Hall, 2011).

309 In the rest of this paper, we approach the civic epistemological opportunities of disasters through  
310 four key themes within a co-production framework, summarised in Figure 1 – though it should be  
311 noted that there are connections and links between and within the boxes shown in the figure.

312 Initially, we discuss the issue of “locating expertise” – the institutional and networked context of  
313 expert advisory groups in society. This is important in disasters because disasters are time-critical.

314 There is rarely time to assemble an expert advisory group in a crisis. We use some recent examples  
315 to illustrate this issue, which ultimately concerns the ways in which science and social order are co-

316 produced around disasters. We then discuss the challenge of “representing expertise”. This refers to  
317 the ways in which science is represented to stakeholders. In particular, it examines the  
318 representation of uncertainty – a major problem at L’Aquila, for example. One of the problems with  
319 uncertainty in an acute setting is that it undermines the perceived authority of science and tends to  
320 result in the rhetoric of “objectivity”. The co-production of science and social order, however,  
321 requires a careful framing of uncertainty. Thirdly, we address the context of expertise. Much  
322 valuable social scientific research in DRR has concerned the role of local knowledge and of local  
323 perceptions of risk. Co-production and the negotiation of civic epistemological ruptures requires an  
324 awareness of the context of scientific advice, and many studies have provided insights into the  
325 integration of local and scientific knowledges for DRR. Finally, we consider the issue of “governing  
326 expertise”. When stakes are high, it is critical that experts’ positions in relation to governance and  
327 responsibility are clear. While expertise should be accountable in a democracy, it should also be  
328 protected.



329

330 Figure 1. Summary of issues concerning advisory practice around disasters.

331 **The civic epistemologies of DRR**

332 In this section, we systematically review the four dimensions identified in Figure 1, using the L’Aquila  
 333 example and a broad range of other examples from the literature.

334 *Locating expertise: Flexible co-production*

335 Links between scientific advice and social order in the context of disasters can be demonstrated in a  
 336 number of case studies. To give an example, the shock of a volcanic eruption is all-engulfing for a  
 337 community that exists on the slopes of the volcano and requires rapid and effective adaptation. The  
 338 volcanic eruptions on Montserrat, West Indies, began in 1995 and continued episodically until 2010.  
 339 While no lava has erupted since 2010, however, the eruptions are not considered over because of



340 ongoing unrest (e.g. MVO and SAC, 2014). At the onset of the eruptions, locating scientific advice  
341 was a priority, yet advice that was given prior to the imminent threat had failed to penetrate the  
342 government's consciousness: a report by Wadge and Isaacs (1988) had been sent to the local  
343 government, but was not acted upon (Donovan and Oppenheimer, 2014). This is a documented  
344 problem in volcanic disasters (e.g. Sparks, 2007; Donovan and Oppenheimer, 2011; see also Wisner  
345 et al, 2012): prior to the disaster, there may be little political will to engage with the risk or establish  
346 institutional frameworks for dealing with it (e.g. Wisner et al., 2011). In many cases, the expertise is  
347 "latent" within the scientific community and has no means to penetrate policy. Referring to  
348 Soufriere Hills and Montserrat, Fergus (2004) wrote:

349 There is no totally satisfactory and logical explanation for the neglect of the volcano and its potential hazards  
350 except the imprecision of volcanology as a science, the ambivalence of the predictions as a result of that  
351 imprecision, and the long time-lapse between the last eruption and 1995.<sup>2</sup>

352 Fergus, a former deputy Governor of the island, felt that, given the evidence – which included  
353 several seismic crises in the twentieth century – it "should not have been a secret" (Fergus, 2004)  
354 that the volcano was reactivating. The fault lay, he felt, with the lack of uptake of the Wadge and  
355 Isaacs report by the local government. Scientific knowledge was not adequately communicated or  
356 received. Thus, the eruption came as a shock to many inhabitants, and the act of coming to terms  
357 with it was essentially one of mourning and re-identification with their reshaped island (Skelton,  
358 2003; Donovan et al., 2011). The failure of scientific knowledge to penetrate planning was an  
359 obstacle to flexible and rapid management of the eruption in 1995 (Clay et al., 1999). There were no  
360 volcanologists on Montserrat itself, so scientists from the University of the West Indies, from  
361 universities in the UK, and from the Volcanic Disasters Assistance Program in the USA were brought  
362 in to provide the necessary information. Unfortunately, as noted above, there is a high level of  
363 uncertainty in a volcanic crisis, and in 1995 there was a lack of consensus between these groups

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<sup>2</sup> The volcano had not erupted since settlement, in 1632.

364 concerning the likely course of the eruption (Aspinall et al., 2002). This combined with a lack of  
365 institutional, legislative and political frameworks for managing the eruption, and resulted in the  
366 formation of institutions, laws and committees over a period of several years of chronic crisis  
367 (Pattullo, 2000; Clay et al., 1999). There were also differences in the pace of acquiring scientific  
368 structures (which occurred fairly rapidly) and formalising them (which took several years – the  
369 volcano observatory was formalised by government Act in 1999 and the scientific advisory  
370 committee in 2003, partly in response to fear of litigation; Donovan et al., 2012d).

371 As noted above, critics of the scientists who were convicted in the court cast concerning the L'Aquila  
372 earthquake argued that the selection of these scientists was politically motivated, and that their  
373 political allegiances impacted their judgement (e.g. Hall, 2011). The ways in which governments  
374 select scientists are varied, but often involve informal networks, or key, government-backed  
375 scientific institutions (e.g. Jasanoff, 2005; Donovan and Oppenheimer, 2012). This snowball-like  
376 method of selection depends upon the integrity of those involved in suggesting the names of people  
377 who may be more appropriate – particularly in time-critical contexts. The source of scientific  
378 authority must also be considered: Jasanoff (2005) notes that in the UK, choice of experts may  
379 depend as much on previous service to society as on knowledge. There are also some important  
380 differences between nations concerning how authority is constructed, and this relates very closely to  
381 the accessibility of expert advice. In Iceland, for example, volcano monitoring data are publically  
382 available (e.g. Bird et al., 2008), allowing members of the public to draw conclusions from the same  
383 data as the scientists. Reports of the scientific interpretations of the volcanic eruptions were readily  
384 available online. In the UK, however, the “ash crisis” of 2010 came as a surprise for which the  
385 government was not prepared (Donovan and Oppenheimer, 2011, 2012). It instigated a “Scientific  
386 Advisory Group in Emergencies” (the SAGE mechanism) to provide advice, but the selection of SAGE  
387 members and the content of the meetings themselves were not clear nor public. In 2011, the  
388 secrecy surrounding the SAGE was criticised by the Select Committee (House of Commons, 2011);

389 Donovan and Oppenheimer, 2012): there was insufficient clarity about the information on the basis  
390 of which decisions about volcanic ash had been taken, and a breakdown of communication between  
391 scientists and government about the risk prior to the eruption (Oppenheimer, 2010). Minutes of  
392 SAGE meetings have since been published, and a strength of the SAGE mechanism is its flexibility.

393 These examples demonstrate that advisory mechanisms for disasters have to be both pre-emptive  
394 and responsive. There is continuous dialogue between the social progression of a disaster and the  
395 scientific advisory process, as decisions and the knowledge-claims on which they are based are  
396 questioned. Other forms of knowledge and interpretation are frequently applied in the knowledge-  
397 testing process. These can include past experience, local knowledge, (post)colonial discourses,  
398 changes in relationship between people and land, people flows and networks, and cultural memory  
399 (e.g. Cashman and Cronin, 2008). All of these issues impact social and scientific knowledge  
400 production and require sensitivity (e.g. Allen, 2007).

401 The involvement of international scientific advisors is common in seismic and volcanic hazard  
402 assessment. Examples of this include the provision of advice from Japanese scientists to Iranians  
403 following the Bam earthquake in 2003 and the involvement of the USGS Volcanic Disasters  
404 Assistance Programme (VDAP) in a number of volcanic crises, including Pinatubo (Newhall and  
405 Punongbayan, 1996), Merapi in 2010 (Surono et al, 2012) and indeed on Montserrat in 1995, albeit  
406 briefly (Aspinall et al., 2002). In each of these cases, local knowledge was combined with the  
407 experience and knowledge of the international teams in order to manage a local or regional-scale  
408 event. The presence of scientists from multiple cultures inevitably provides differing perspectives,  
409 especially if a local culture has a much greater awareness of the human geography of the region. A  
410 key lesson might thus be the importance of reflexivity in science: awareness of the potential for  
411 social circumstances or personal experience to affect risk judgements. A further, critical issue for  
412 other contexts might be the involvement of multiple scientific agencies with different structures and  
413 experiences. These circumstances require a clear, transparent and systematic approach for

414 identifying and gathering appropriate experts in emergencies, and a flexible system for incorporating  
415 different knowledges and reaching out to different groups (Figure 1).

### 416 *Representing expertise: framing, objectivity and boundary work*

417 This section draws on philosophy of science and probability to examine the process of scientific risk  
418 assessment – often a key part of the advisory process. It also examines the reporting and framing of  
419 such assessments, arguing that the representation of expert advice is a key dimension of the civic  
420 epistemology of disasters (see Figure 1). This may be particularly challenging in volcanic and seismic  
421 risk assessment, because of low probabilities associated with high impacts, and disagreement  
422 between experts concerning the most effective methodology. At L’Aquila, for example, there were  
423 claims, after the event, that the methods used in seismic hazard assessment were inadequate or  
424 failed to use all available knowledge. These issues are actively debated within risk assessment  
425 discourses in both seismology (e.g. Castanos and Lomnitz, 2002; Marzocchi and Zechar, 2011;  
426 Jordan, 2013) and in volcanology (Donovan et al., 2012b,c; Marzocchi et al., 2012). Furthermore,  
427 unpopular decisions may lead to public interrogation of scientific method and the undermining of  
428 scientific advice. This occurred to a degree during civil cases brought in Montserrat in 2002-3  
429 (Donovan et al, 2012d): local people criticised the scientists because of an evacuation that lasted for  
430 nine months. This led to a civil case against the Governor of the island, and to negative relationships  
431 between scientists and society (e.g. Aspinall, 2011). Communication strategies are thus particularly  
432 important, and in a democratic society these include transparency about both knowledge and non-  
433 knowledge in scientific reports.

434 A characteristic of volcanic and seismic hazards is the high uncertainty that surrounds them. This  
435 invariably impacts the use of scientific advice – and is a critical element of its communication. For  
436 example, Haynes et al (2008) found that Montserratians were more accepting of science when they  
437 had grasped that it could not give the answers they wanted. Many decisions have to be made on the

438 basis of best estimates, frequently expressed as probabilities. The epistemological status of  
439 probability is problematic (Hacking, 2001; Popper, 1959), but the provision of probabilistic estimates  
440 nevertheless constitutes a form of knowledge-claim because it asserts that certain events are  
441 thought to be more or less likely based on *fragmentary* knowledge. This liminal form of knowledge is  
442 essential in risk management: quantitative assessment greatly facilitates the monitoring of whether  
443 or not risk has increased from one period to the next, for example. Nevertheless, it also requires  
444 qualitative framing so that the claim and the reasoning behind it – the true scope of the fragmentary  
445 knowledge – are transparent (Donovan et al., 2014). This involves appropriate use of language. For  
446 example, scientific definitions tend to oppose “objective” and “subjective” in ways that are not  
447 helpful for transparency or the progression of scientific advice (Aspinall, 2012; Donovan et al.,  
448 2012b): as Kuhn (1977) argued, the concepts are not opposed but rather define different ideas.

449 Further to this, when knowledge claims are controversial, scientists may be “subjectivised” by the  
450 public – arguably a similar phenomenon to L’Aquila. Scientists may be torn between defending the  
451 “objectivity” of science and acknowledging the uncertainty inherent in the natural system. This  
452 points to two important aspects of managing non-knowledge: transparency and awareness of  
453 positionality (reflexivity; Donovan et al., 2014). Facilitating the representation of expertise within the  
454 social context is an important aspect of risk management, and involves acknowledgement of the  
455 limitations of knowledge as well as its implications. Disasters can be negotiated through adaptive  
456 methodologies for representing uncertainty and risks, and by the continued examination of claims  
457 made by expert groups. Social scientific input into the presentation and communication of scientific  
458 advice would be extremely beneficial here: the framing of expert advice is crucial in preventing  
459 situations like L’Aquila, as has been demonstrated repeatedly in Science Studies (e.g. Irwin, 2001;  
460 Miller, 2000; Hajer,2003). It would also ensure that policymakers and the public are not misled about  
461 the uncertainty in science. The importance of representing science and uncertainty accurately has  
462 been witnessed in other aspects of environmental geography (such as climate change), and human

463 geographers are ideally positioned to carry out forensic research on past extreme events and  
464 develop best practice guidelines that are effective.

### 465 *Contextualising expertise: knowledge identities and geographies*

466 Civic epistemological thresholds frequently involve the management of a range of cultures and  
467 identities, all of whom are experiencing the event in different ways. This can include past  
468 experience, local knowledge, (post)colonial discourses, changes in relationship between people and  
469 land, people flows and networks, and cultural memory (e.g. Cashman and Cronin, 2008). All of these  
470 issues impact social and scientific knowledge production and require sensitivity. One important  
471 emerging method for the integration of such knowledges is Participatory Mapping (Cadag and  
472 Gaillard, 2012), and other examples are given by Lane et al (2011): local and scientific stakeholders  
473 interacting to learn from past events and prepare for the future. However, in the case of very low  
474 probability events, or those where there is a high dependence on experts, it is critical that all  
475 information is available to governments very quickly. While formal participatory methods may not  
476 be readily available, particularly in a crisis, some degree of engagement with the public is helpful for  
477 establishing both authority and accountability (e.g. Haynes et al., 2008). There are thus two aspects  
478 to this theme: the cultures and identities of experts and those of the at-risk community.

479 Taking this further, we might suggest that the presentation and application of scientific advice also  
480 requires input from social scientific studies of risk perception and communication in these different  
481 contexts (e.g. Douglas and Wildavsky, 1982; Sjoberg, 2000; Slovic, 2000). For example, Gaillard  
482 (2008) noted that people living close to Mount Pinatubo perceived volcanic risks as high, but showed  
483 that in spite of this, many will take risks because they are more concerned with the daily challenge of  
484 mitigating poverty. Risk tolerability<sup>3</sup> varies in space and time: there is too much complication from

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<sup>3</sup> Risk tolerability refers to the level of risk that an individual or group is willing to accept. It has been shown to vary according to the nature of the risk, as well as the socio-economic status and characteristics of the individual or group (e.g. Aven and Renn, 2009).

485 non-numerical sources such as cultural conditioning (cf Kahan et al., 2009). The implication from this  
486 argument is that risk scales<sup>4</sup> could easily become chaotic, being socially, politically, culturally,  
487 historically and geographically specific – an example being the particular case of small islands (e.g.  
488 Pelling and Uitto, 2001; Tompkins, 2005). Insight into the types of risks that people in a community  
489 face on a regular basis, their views about different risks and their trust in different institutions can  
490 inform risk assessments, both through addressing relevant questions and through making  
491 comparisons with well-known risks. Furthermore, they inform communication and outreach  
492 activities that help to build resilience (see for example Ben Wisner’s work on social capital in  
493 megacities, Wisner 2003).

494 Risk-taking in a volcanic or seismic environment is ultimately a function of space and time (Massey,  
495 1999): it is human and physical, but not merely in definition; it is on the interface between human  
496 and physical in its realisation by communities and by scientists. Understanding the relationship  
497 between knowledge, expertise and experience in different cultural contexts provides insight into the  
498 risk communication process during the negotiation of disasters. Risk communication and perception  
499 studies are important in understanding the differences between cultures, and participatory methods  
500 that include scientists, officials and members of the public may be particularly important in building  
501 social relationships prior to hazard realisations (see for comparison O’Brien et al., 2008; Brown and  
502 Damery, 2002; Morss et al., 2005).

### 503 *Governing expertise: responsibility and accountability*

504 The previous sections have commented on the types of expertise and (non-)knowledge claim that  
505 may be made during a crisis and their relationship to specific geographies. This section returns to the  
506 issue raised in the introduction about responsibility: how is the relationship between science and  
507 society governed? Again, this is geographically defined and the level of legal protection enjoyed by

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<sup>4</sup> Such as the UK Chief Medical Officer’s scale, which ranks specific values representing risks as “high”, “medium”, “low” etc.

508 expert advisors varies around the world (Aspinall, 2011). It may also not be clear to scientists at the  
509 time of accepting an advisory role – particularly during a crisis. The complexity of governments, and  
510 the relationships between advisory structures, decision-makers and civil officials, may vary  
511 considerably with geography (Donovan and Oppenheimer, 2015). For example, while Iceland has a  
512 permanent structure for advice from scientists concerning earthquake and volcanic hazards, such a  
513 structure does not exist in the UK – resulting in the invocation of the “SAGE” mechanism in 2010  
514 (Donovan and Oppenheimer, 2012). This was effective, but took time to assemble. On Montserrat,  
515 too, the complexity of a colonial governance structure presented a challenge for scientists (Donovan  
516 et al., 2013). The UK-appointed Governor had personal responsibility for the lives of the people on  
517 the island, and in 1996 passed a law allowing mandatory evacuations. Since these evacuations were  
518 based on scientific advice and led to lawsuits, scientists had to give evidence and there were  
519 concerns about their legal status (Aspinall and Sparks, 2004; Donovan et al., 2012d). There is a  
520 balance to be achieved between ensuring that scientists acting in good faith are protected, and that  
521 there is a level of accountability.

522 In terms of accountability, the role of scientists in a democracy has been scrutinised both in the  
523 Science Studies literature (e.g. Wynne, 1989, 1992; Shackley and Wynne, 1995, 1996; Jasanoff, 2004,  
524 2005, 2007; Brown, 2009; Fischer, 2010) and in the sociological studies of risk (e.g. Beck, 1992;  
525 Giddens, 1999). The knowledge that scientists (may) possess and that governments and publics need  
526 gives the former a power that potentially threatens the democratic governance of risks (Beck, 1992).  
527 This may be exacerbated in an emergency, when there is a clear need to identify experts rapidly and  
528 dependence on experts is very high. This can lead to blurred boundaries, since, for example, advice  
529 from a scientist that a particular area is unsafe is very likely to result in evacuation even if there are  
530 very high uncertainties – and scientists may be blamed (Aspinall, 2011; Donovan et al., 2012d).  
531 Conversely, scientists themselves may politicise their advice (e.g. Pielke, 2004). Clarity surrounding



532 the role of experts as advisors is crucial, both for their security and for the management of post-  
533 disaster criticism.

534 Responsibility in the context of scientific advice also rests with citizens, however, since there is often  
535 a choice in buying land in known hazardous areas. This is a key distinction in hazards research,  
536 because urban development has frequently preceded the identification of hazardous areas.  
537 Responsibility in this context is intensely local. Expertise becomes embedded in new ways in an  
538 intense situation (Donovan et al., 2013). This depends in part on its role or institutional framing prior  
539 to the shock, but also on particular local political, social and scientific issues that arise in a crisis and  
540 that require flexible institutional practices. There is therefore a balance between ensuring that  
541 science is in some way accountable, and ensuring that expert advisors are legally protected (e.g.  
542 Alexander, 2014; Aspinall, 2011).

## 543 **Conclusions: Science Studies approaches for increasing resilience to** 544 **environmental risks**

545 The focus on reducing social vulnerability prior to disasters has tended to ignore or underestimate  
546 the importance of scientific input, and to suggest that “hazard” is only the realm of scientists. Thus  
547 the traditional formulation, risk = hazard x vulnerability (sometimes with terms for “mitigation”,  
548 “capacity” and “exposure”), can result in a misleading separation of scientific and social scientific  
549 aspects of disaster research because the framing of the hazard affects vulnerability. The extensive  
550 social scientific focus on vulnerability has produced some very important results, but it has generally  
551 failed to consider the epistemological implications of disasters and the co-production of science and  
552 social order that occurs in their management. To do so requires a coherent understanding of the  
553 dimensions of civic epistemology and the ways in which scientists construct their authority – a rich  
554 field for social science. Disasters produce civic epistemological ruptures – changes in the ways that  
555 societies test and use knowledge. The relationships between science, scientists, decision-making and

556 society clearly defined the events at L'Aquila. It is these relationships that dominate in the  
557 management of disasters, and they are themselves dependent in part on the way that knowledge is  
558 produced, tested and applied in a context of high uncertainty and short timescales.

559 The framework presented in this paper has focussed on four dimensions of scientific advisory  
560 practice for disasters. There were problems with all of these dimensions at L'Aquila. Scientific advice  
561 was kept aloof from the public in an attempt to follow a "linear model" and the selection of experts  
562 was criticised, advice was not widely trusted, the uncertainty on the likelihood of an earthquake was  
563 not adequately or appropriately communicated, and the accountability and responsibility of  
564 different groups was not clear. L'Aquila is also an important opportunity, however, to learn from the  
565 problems that arose and to formulate strategies for the management of scientific advice in time-  
566 critical contexts. We have used this example, together with other recent volcanic and seismic crises,  
567 to demonstrate the importance of co-production as a framework for disaster management, and to  
568 show some of the dimensions of the civic epistemology that this involves. The totality of disasters,  
569 particularly volcanic eruptions and earthquakes, does make them a special case – an "act" by the  
570 natural system that is identifiable in time and space but whose impacts may be much less well  
571 defined. The stakes in these circumstances can be very high indeed, but their rarity is such that  
572 preparations may not have been made in advance. Increased awareness of the complexity of the  
573 "local knowledge" and "scientific knowledge" that are discussed regularly in the disaster  
574 management literature would aid the construction of meaningful institutional practices and  
575 flexibility prior to disasters. In volcanic eruptions in particular, there will always be a high  
576 dependence on scientific advice; ensuring and understanding its reliability, authority and integration  
577 with social learning is thus of paramount importance. The role of place, spatial constructions of risk  
578 and cultural context in framing disaster risk provides a rich opportunity for multidisciplinary studies  
579 led by geographers. Human and physical approaches, though epistemologically and ontologically  
580 diverse, can be combined in the context of advisory science. However, the tendency of geographers

581 to bifurcate in this way can also be detrimental, and this is closely reflected in the hazard –  
582 vulnerability split in DRR.

583 In order to take DRR forward, then, it is necessary for human and physical geographers, physical and  
584 social scientists, to be explicit about their epistemological frameworks. This has been realised in part  
585 by several recent projects, but ontologically and epistemologically the two sides frequently remain  
586 embedded in their scientific or social scientific disciplinary training. Yet this is changing within  
587 geographical studies. Lane et al (2011) describe an example of this in flood risk management,  
588 demonstrating the potential for collaborations (see also Morss et al., 2005 and Demeritt et al.,  
589 2010). In the context of DRR, these collaborations have to be transdisciplinary (involving  
590 policymakers, the public and NGOs) in a bottom-up-top-down approach (e.g. Wisner et al., 2012).  
591 Furthermore, the Understanding the practice of scientific advice prior to, during and after disasters  
592 will not prevent their occurrence, but could help to ensure that they are manageable rather than  
593 crippling.

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