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Research, part of a Special Feature on Risk mapping for avian influenza: a social-ecological problem

From Risk Assessment to Knowledge Mapping: Science, Precaution, and Participation in Disease Ecology

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ABSTRACT. Governance of infectious disease risks requires understanding of often indeterminate interactions between diverse, complex, open, and dynamic human and natural systems. In the face of these challenges, worldwide policy making affords disproportionate status to “ science-based” risk-assessment methods. These reduce multiple, complex dimensions to simple quantitative parameters of “outcomes” and “probabilities,” and then re-aggregate across diverse metrics, contexts, and perspectives to yield a single ostensibly definitive picture of risk. In contrast, more precautionary or participatory approaches are routinely portrayed as less rigorous, complete, or robust. Yet, although conventional reductive–aggregative techniques provide powerful responses to a narrow state of risk, they are not applicable to less tractable conditions of uncertainty, ambiguity, and ignorance. Strong sensitivities to divergent framings can render results highly variable. Reductive aggregation can marginalize important perspectives and compound exposure to surprise. The value of more broad-based precautionary and participatory approaches may be appreciated. These offer ways to be more rigorous and complete in the mapping of different framings. They may also be more robust than reductive–aggregative appraisal methods, in “opening up” greater accountability for intrinsically normative judgements in decision making on threats like pandemic avian influenza.

Key Words: *ambiguity; ignorance; participation; precaution; risk; uncertainty.*

SCIENCE, PRECAUTION, AND PARTICIPATION IN DISEASE ECOLOGY

Worldwide, the governance of threats from infectious disease is increasingly reliant on the quality of underlying processes of policy appraisal that inform disease surveillance, control and management, and emergency response strategies, for example. We use the term “policy appraisal” to refer to the means and manner in which knowledge is produced, and social learning is promoted, in order to inform policy (Wynne 1995). It is on this basis that implicit institutional commitments are formed and explicit decisions are justified (Stirling 2008).

The governance of pandemic risks requires a particularly diverse array of policy-appraisal processes. This is because the social, ecological, and technological systems involved are so extensively distributed, and so highly complex, dynamic, and uncertain (Scoones et al. 2007). The importance of effective appraisal is amplified by the high human and economic stakes, and the diverse ways that possible governance interventions may prove intractable, ineffective, or counterproductive (Leach et al. 2007). The challenges are compounded by the fact that policy options, including frameworks for appraisal, are typically ill defined, hotly contested and path dependent (Stirling et al. 2007).

Under conditions of limited time, resources, and attention, appraisal of possible responses to threats of pandemic avian influenza present formidable challenges for governance. Over the last decade, the international response to highly pathogenic avian influenza (and specifically the avian virus H5N1) has been shaped by three overlapping, but distinguishable, “outbreak narratives” that define the problem and suggest solutions (Scoones and Forster 2008). The first is a strong narrative linking veterinary concerns with agriculture and livelihood issues: “It’s a bird disease, and it affects people’s

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livelihoods.” The responses here have centered on veterinary control measures and industry “restructuring,” with the World Organization for Animal Health (OIE) and United Nations Food and Agriculture Organization (FAO) being at the center of the debate. Second, there is a human public health narrative, that has certainly dominated media and political concerns: “Human to human spread is the real risk, and could be catastrophic.” Here, a combination of drugs, vaccines, and behavior change dominates the response. This response is centered on the World Health Organization (WHO), with the United Nations Children’s Fund (UNICEF) and a number of other NGOs being important players. Finally, there is a narrative focused on pandemic preparedness: “A major economic and humanitarian disaster is around the corner and we must be prepared.” Responses in this case focus on civil-contingency planning, business continuity approaches, and containment strategies. This concerns a much wider network of industry players and consultants, linked to different branches of government (notably, prime ministers’ and presidents’ offices, and finance ministries) with concerns about the economic fallout of any pandemic. The humanitarian community (United Nations agencies, the Red Cross, development NGOs, and others) is also important.

We will review and discuss how these three narratives condition processes of policy appraisal. Each justifies distinct sets of interventions, obscuring other narratives and their associated contrasting problem framings and alternative responses. The dominant trio of narratives also compete for attention and resources, with different actors deploying a variety of arguments and information to prioritize their favored solutions. As a result, serious issues are raised over the respective roles for scientific analysis, precautionary intervention, stakeholder deliberation, public engagement, and wider political accountability.

In the face of these kinds of challenges, beleaguered decision makers increasingly invoke the authority of “evidence-based decision making” (Nutley et al. 2007). Originating in the health sector, this discourse is a key theme in the global governance of infectious disease (WHO 1999). In the particular field of avian influenza, as elsewhere, this is routinely taken to mean the adoption of so-called “science-based” (WHO 2006a) approaches to policy appraisal. These include a range of structured quantitative assessment methods, including an epidemiological approach, and other forms of modeling (Suter 1990), variously coupled with probabilistic reasoning (von Winterfeldt and Edwards 1986), cost–benefit analysis (Hanley and Spash 1993), life-cycle assessment (van den Berg et al. 1995), multi-attribute evaluation (Dodgson et al. 2001), and decision-tree methods (Clemen 1996). When applied to challenges such as the understanding of avian influenza, such methods are often referred to collectively as “science-based risk assessment” (Byrd and Cothern 2000). This language of science-based risk assessment remains a prominent feature of contemporary policy discourses in this area, at international and national levels alike.

In global disease management (as elsewhere), debates over the application of such “science-based” methods often acquire strongly normative overtones (Taverne 2005). In the public health area in particular, there is an increasingly prominent notion that complex, uncertain, and contested decisions can be determined by “sound science” (WHO 2006b). This is so, because established risk-assessment techniques are conventionally held to offer the most “rigorous inputs and rules” for decision making (Peterson 2006). As such, risk assessment is also argued to be more rational than other forms of policy appraisal, because it involves the systematic weighing up of “objective” aspects of benefit and harm, rather than being driven by subjective anxieties or agendas (Graham and Wiener 2000). Risk assessment is also generally regarded as being “complete” in scope, allowing “synoptic” extension of attention to all areas of relevant specialist expertise (Collingridge 1980). As a consequence, the results obtained by these “science-based” methods are held to present the most “robust” possible bases for decision making (Byrd and Cothern 2000).

It is from these kinds of received wisdom that concerns are presented over the efficacy and value of more “participatory” and “precautionary” approaches to policy appraisal (Taverne 2005). For some, public participation (in all its various forms) seems to dilute the role of expertise, and so constrain the completeness of appraisal (Lloyd 2000). Likewise, by moving away from exclusive reliance on scientific disciplines, provision for greater participation by nonspecialists seems to entail a compromise on the systematic rigor of “sound scientific” assessment (Wolpert 1992). Such concerns are the basis for a well-established and influential body of criticism of participatory approaches to "science-based" environmental and health policy issues (Rossi 1997, Sanders 1997, Collins and Evans 2002, Campbell and Currie 2006, Dietz and Stern 2008).

In terms of providing the best possible basis for decision making in an area like avian influenza responses, many find it difficult to see how participation can do anything to improve the technical rigor, completeness, or robustness of risk-assessment results. Of course, it may be conceded that, in some circumstances, participatory methods may be useful in communicating results and in securing public trust and compliance (Rowe and Frewer 2000). Participation can enable greater "legitimacy" (and perhaps enhance "democracy") in wider governance (Fischer 1990, Sclove 1995, Bohmann 1996). But, if considered at all, these more overtly normative issues are typically seen more as matters for "risk management" than "risk assessment" (Renn 2006). Similar concerns are held in many quarters over the use of the precautionary principle in policy appraisal. Of course, in the face of major large-scale threats like those to human health from avian and pandemic influenza, there is little controversy around some role for precaution as a possible normative presumption in risk management (WHO 2005). With respect to the practice of risk assessment in policy appraisal, however, precaution becomes much more controversial (Commission of the European Communities (CEC) 2000, Woteki 2000, Martuzzi and Tickner 2004). Although found in many forms (de Sadeleer 2002, Fisher 2002, Trouwborst 2002), an early classic formulation of the precautionary principle neatly encapsulates the key issues. According to Principle 15 of the Rio Declaration on Environment and Development: "...Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent [harm]..." (United Nations 1992).

Numerous questions are raised. Exactly how are we to appraise criteria of "seriousness" or "irreversibility," so as to trigger the application of this principle (Sand 2000)? How is "scientific certainty" to be measured, and under what circumstances might this ever be judged to be "full" (Peterson 2006)? Unless through "science-based" techniques (like risk and cost–benefit assessment), what is to be the basis for determining whether a proposed measure is actually "cost effective" (Morris 2000, Woteki 2000)? And where (as is often the case in the governance of disease), the policy choices lie between different possible forms of harm (as well as their respective costs and benefits), how are we to apply precaution to choices between different forms of contending risks (Graham and Wiener 2000)? Again, we hear serious concerns over rigor, completeness, and robustness.

In short, it is widely feared that adoption either of precautionary or participatory procedures in the appraisal of threats like those from infectious diseases implies some kind of rejection of risk assessment (Taverne 2005). This is, in turn, held to lead to potentially highly inefficient and even counterproductive outcomes (Majone 2002). To many such critics, the increasing prominence of participation and precaution in risk policy is grounded not on substance or merit, but on the spurious influence of overblown public anxieties (Sunstein 2005), the politicization of science by "fundamentalist" lobby groups (Taverne 2005) and self-interested sensationalism in the media (Morris 2000). The application of participatory or precautionary approaches to the governance of avian influenza may thus be seen as a costly, protracted, and misleading form of "political correctness" (Lloyd 2000).

We will examine some of the issues underlying these concerns, as they apply to broad areas of risk policy, particularly as encountered in the field of avian and pandemic influenza. We will make a case that neither precaution nor participation necessarily present these kinds of tensions, dilutions, or compromises with "science-based" disciplines. Setting to one side the role of normative aspirations in wider risk management and governance, this paper will specifically address the "sound science" critique of precaution and participation at the point where it is apparently strongest and most specific: with regard to policy appraisal (Stirling 2008). We will argue here that when implemented in appropriate ways, both precaution and participation can actually enhance the rigor, completeness, and robustness of policy appraisal (and associated decision making), beyond what is achievable through risk assessment alone.

We will begin in the next section by examining in some detail the nature of "science-based" risk assessment itself. In the third section, attention will turn to some of the qualifications and constraints on the efficacy of risk-assessment methods. In the fourth section, we will consider the methodological responses to these challenges, of a kind that are entirely consistent with “sound scientific” and “evidence-based” aspirations in policy appraisal. This will then form a basis for a return (in the fifth section) to the implications of precaution and participation for greater rigor, completeness, and robustness in appraisal of infectious disease risk. It will be argued in conclusion that policy making in this area needs to move away from present preoccupations with “sound scientific” risk assessment and towards a complementary emphasis on more broad-based (precautionary) and open-ended (participatory) approaches to the “mapping” of contending knowledges and perspectives.

“SOUND SCIENCE” AND EPIDEMIOLOGICAL RISK ASSESSMENT

In seeking to legitimize and justify governance interventions to counter threats of avian influenza pandemics, bodies such as the WHO increasingly refer to the need for more “evidence-based” or “science-based” approaches to disease management (WHO 1999, 2006a). As argued above, this indicates a growing prominence for notions of “sound scientific” risk assessment (WHO 2006b). Although this includes a diverse range of methods (Morgan et al. 1990), the common “science-based” status is typically held to refer to two specific shared properties (Byrd and Cothern 2000). First, these techniques reduce the multiple, complex, and indeterminate dimensions of knowledge to just two readily quantified kinds of parameter: outcomes and probabilities. Second, these parameters are then “re-aggregated” in carefully disciplined ways to yield an ostensibly simple scalar representation of “risk.” The resulting numbers can then be taken objectively to justify certain particular interventions over others. In this way, for instance, routine comparisons of morbidity risks from different diseases aggregate across different subpopulations and kinds of morbidity. They also reduce to a common metric contrasting cases involving low probabilities of high levels of morbidities and high probabilities of low levels of morbidity.

Whether precisely specified or not, these “reductive–aggregative” understandings of risk offer compelling ways to order otherwise recalcitrant arrays of possible interventions, agents, contexts, vectors, pathologies, populations, and distributions (Stirling 2003). They allow articulation of a range of diverse knowledges and priorities, and a host of divergent understandings of what constitutes “evidence,” “cost,” “benefit,” or “harm.” Through reduction and aggregation, they derive apparently definitive resolutions for many of the messy political complexities of disease-risk governance. Such is their utility, authority, and facility, that these “science-based” appraisal procedures often serve a much more determining function than the overt intention of merely informing policy making (Jasanoff 1990). Through the potent, prescriptive force of reduced and aggregated “sound scientific” representations of risk, they offer a highly expedient means to legitimize or defend what are typically highly uncertain and hotly contested policy options and aims (Collingridge 1982). Even if the underlying calculative procedures are performed only symbolically or informally, the associated quantitative idiom is routinely held to confer a high degree of authority and stochastic reliability (Porter 1995). Indeed, the received wisdom is that it is only through this kind of “science-based” procedure that we can properly justify rational decision making over strategic priorities, resource allocations, or policy interventions in disease management (Stirling 2008).

There is no denying the potency and facility of “science-based” risk assessment under particular circumstances and assumptions. However, as with any approach, questions arise over the nature and significance of the limiting conditions. It is these generic constraints that remain relatively neglected in burgeoning mainstream policy discourses on “sound scientific” management of infectious disease risks. The problem is that behind the apparently clearcut concepts of “probability” and “outcome,” these procedures involve at every stage a host of often-hidden assumptions, conventions, and protocols. These factors are important, because each admits the possibility of a variety of different (but equally scientific) “framings” of analysis, often with significant consequences for the final results (Goffman 1986). In order to understand the sometimes profound practical and theoretical implications, each of these two key parameters in “science-based” risk assessment needs to be considered in more detail.

“Outcomes” reflect the different relevant things that might happen as a consequence of some set of possible interventions or contingent “states of the world.” These may be seen as discrete scenarios, or increments on some continuum of consequences. Either way, they can be quantified under a range of different possible scales of magnitude. In policy making on infectious-disease epidemiology, for instance, outcomes may variously be characterized in terms of the incidence or severity of different forms of morbidity or mortality, or partitioned according to variants of the pathogen, pathology, vector, or population in question. Alternatively (or in addition) such outcomes may be articulated with other factors to yield scenarios (or increments) of cost, benefit, or harm that may, in turn, be calibrated in a host of different ways.

Thus, in the case of avian influenza, outcomes can be defined, for example, in terms of potential impacts of pandemic influenza on human mortality. Up to 150 million deaths may occur in a major global pandemic, according to some estimates (although there are huge variances in the numbers quoted). Human mortality impacts may also be more tightly defined, in relation to particular groups at risk (for e.g., women or children handling poultry). Potential economic impacts of a global pandemic are also quoted, with some estimating the cost at U.S.$3 trillion. Cast in a different way, outcomes may be seen in terms of lost livelihoods and impacts on poverty and well-being. These outcomes may emerge from the response itself, as culling campaigns have resulted in around 2 billion chickens being slaughtered, many of which were backyard birds owned by poor families in developing countries (Scoones and Forster 2008).

Whatever the detail, the metrics that are adopted for quantifying such consequences hold important implications for the relative ordering of different interventions or outcomes. Yet associated science-based treatments of “disease risk” are typically conducted as if grounded in some more transcendently objective framework, irrespective of the particular chosen denominators and associated contingencies in their measurement.

Once outcomes have been defined as a set of discrete states or intervals on some chosen scale of magnitude, “probabilities” are then conventionally thought of as reflecting the respective objectively established expected relative frequencies associated with each. They take the form of a fractional number between zero and one (with zero reflecting impossibility and one expressing certainty) and sum to one over all possibilities. As with the magnitudes of outcomes, the apparently synoptic nature of the probability parameter can mask important gaps and contingencies. For instance, numerical probabilities may alternatively be derived from ex post epidemiological surveillance or ex ante theoretical modeling. Likewise, the evidence in question may reflect structured Bayesian analysis of “prior” and “posterior” information (Burgman 2005) or more informal elicitations of subjective qualitative expert judgements rendered in convenient numerical form. Either way, discussions of “sound scientific” approaches to risk tend not to be explicit over the sourcing or quality of these contrasting provenances for probabilities and their associated limitations (Funtowicz and Ravetz 1990). They tend to treat quantitative expressions of probability in a disembodied way, without reference to the associated contextual particularities and conditions (Hacking 1975).

This way of thinking about appraisal can encourage an impression that the scope in which incomplete knowledge has been addressed is more encompassing than is actually the case. The choice of metric and form of calculation is usually driven by a particular narrative framing, and so presents a picture of outcomes in a certain light, necessarily excluding other alternatives. In fact, probabilities typically address only a subset of the dimensions constituting incomplete knowledge (Wynne 1992). By definition, for instance, they cannot address possibilities that have not been defined or even anticipated (Smithson 1989). With stochastic representations of uncertainty thus treated as effectively more complete and robust than is actually the case, the real risk is that we ignore, and are exposed to, significant residual forms of incomplete knowledge (Faber and Proops 1993). This exposure is all the more problematic if the probabilistic idiom encourages a misplaced confidence in the rigor or completeness of analysis (Porter 1995).

A final set of questions are raised after the magnitudes and probabilities have been constructed in these ways. These concern the utilitarian assumptions under which the numbers are re-articulated (Hanley and Spash 1993). Classically, the aggregate representations of “risk” constructed in risk assessment take the form of a simple “product” of magnitudes and probabilities (Morgan and Henrion 1990). Under similar conditions, then, a 0.001% chance of 10 million deaths can be rendered equivalent to a 1% chance of 10 000 deaths. This scalar understanding assumes a linear relationship between the two parameters of risk, such that the same increment in either component at high or low ends of the scale holds the same evaluative implications. In other words, it tends to downplay the well-known (and entirely rational) practice of attributing varying significance to the same increment of risk, depending on where it falls on a spectrum of overall severity (Hanley and Spash 1993). For instance, the disproportionately disruptive effects of (low probability) risks of morbidities affecting a substantial fraction of a working population may (perfectly reasonably) be prioritized more highly than ostensibly identical (high probability) risks of the same morbidities at lower levels of incidence. Thus, in policy discussions around avian and pandemic influenza, global impacts (and particularly those that affect North America or Europe), even if of relatively low probability, are emphasized over higher likelihood consequences affecting poor chicken producers in urban Asia. Epidemiological models emphasize the importance of "at source" containment and control, in order to reduce the risk of pandemic spread (Ferguson et al. 2005, Longini et al. 2005), but such models focus again on global consequences, rather than on the immediate impacts on local populations of intensive containment measures.

It is these kinds of trade-offs that are obscured by deterministic forms of "sound scientific" risk assessment and associated unitary ideas of "science-based" policy. The models and the metrics tell only part of the story, justifying one narrative, often at the expense of another. This narrowing of scope is amplified by pressures for political justification through prescriptive appraisal results (Collingridge 1982). This confers a premium on the elegance of probabilistic calculus and the ostensibly definitive quantitative idiom (Porter 1995). The incentives and opportunities provided by these techniques for demonstrating sophisticated disciplinary prowess further reinforce this institutional dynamic (Hacking 1975). Nowhere are these challenges more pronounced than in areas where the ecological, social, and technological systems under scrutiny are highly complex, intercoupled, open, and nonlinear in their dynamics (as is the case in the governance of avian influenza). A wide range of uncertainties exist, from the big unknown (will a pandemic happen at all, and if so when?) to the specific unknowns (about the impacts of veterinary control measures, vaccination and drug efficacy, behavior change in situations of crisis, etc.) (Scoones and Forster 2008). Whatever the basis for the associated data, methods, or evaluations, the consequence is that there are multiple ways in which policy discourses in this area may be seriously misled by exaggerated notions of the objectivity or completeness of conventional probabilistic risk assessment.

FROM "EVIDENCE-BASED" TO "EVIDENCE-BOUND" POLICY

The issues discussed thus far may appear rather abstract, and of somewhat academic interest. What might be the practical relevance to real-world policy challenges like the management of threats from avian influenza? In these contexts, the focus is on highly concrete questions over the relative merits of alternative mitigation, prevention, or research strategies. Under the crisis conditions of unfolding epidemics, deliberations over contending acute public-health interventions will be extremely urgent. In such cases, it might be assumed that the tight time frames and high stakes preclude the luxury of considering such seemingly conceptual issues. Unfortunately, however, the practical difficulties that flow from these challenges are not so readily dismissed. Although rarely explored in detail in policy literature on infectious-disease management, the implications of this analysis can be of very immediate and highly tangible importance to policy making (Waltner-Toews and Wall 1997, Waltner-Toews 2000).

"Evidence-based" (reductive–aggregative) risk-assessment techniques have become highly developed in a number of areas for comparative appraisal of policy options. Individual studies or scientific advisory exercises typically express the resulting policy recommendations in quite strongly prescriptive terms. Yet again and again, in fields like energy technologies (Stirling 1997, Sundqvist et al. 2004), agricultural strategies (Stirling and Mayer 2001), pollution regulation (Saltelli 2001), and industrial safety (Amendola et al. 1992), for example, it emerges that the authoritative peer-reviewed literature taken as a whole typically yields far more varied implications for policy than do the stated conclusions of individual studies.

The reason that "sound scientific" expert risk-assessment procedures can yield such contrasting pictures is that the answers that are derived typically depend on the "framing" of analysis (Goffman 1986). Based on a wide literature (Wynne 1987, Jasanoff 1990, Schwarz and Thompson 1990, Gee et al. 2001), Table 1 identifies a series of factors that feature in this general "framing" of science in policy appraisal, of a kind that can lead to radically divergent answers to apparently straightforward questions about risk. As in other areas of policy making, these framing factors can hold profound implications for notions of what constitutes the best strategy in the governance of infectious diseases like avian influenza.

Each of the narratives shaping the dominant policy debate on the international response to avian influenza discussed above is influenced in different ways by these types of framings. Thus, the veterinary-response narrative bounds the problem as a poultry disease, focusing on a particular disciplinary framing of disease eradication, defined by the veterinary profession and associated institutions. The public-health narrative, by contrast, defines the problem in terms of human health impacts, deploying a different set of criteria and methods for coming up with policy options. Thus, a combination of antiviral drugs, vaccines, and behavioral-change efforts are seen to be the core of any response, focused on reducing infection and transmission, as well as ameliorating symptoms, in the face of an outbreak. The pandemic-preparedness narrative bounds the problem in yet other ways. Here the focus is on systemic impacts of a pandemic (e.g., on the functioning of the economy or on humanitarian aid delivery) at broad global, regional, or national scales. Different sources of expertise are drawn on, with concerns about logistics, emergency relief, and contingency planning dominating the debate and, in turn, defining problems and solutions in yet more different ways (Scoones and Forster 2008).

One particularly important way in which framings can become solidified lies in choosing among a variety of possible metrics. Are the risks to be denominated in terms of statistical expressions of mortalities or morbidities across entire populations, across vulnerable subpopulations, or the particular concerns of the most vocal or influential groups? Are impacts accounted for in terms of livelihoods, public expenditures, or aggregate costs to the economy? These, in turn, reflect ambiguities in the possible ways to characterize, bound, and partition the possible disease outcomes and associated economies under consideration. How do we constitute an "outbreak?" What scenarios are envisaged for the dynamic mutation or stabilization of the virus? What different perspectives are there on the potential distributional consequences, and associated implications for the "fairness" of different possible interventions? How does this relate to other concurrent policy imperatives? Are governance challenges approached in terms of efficacy, equity, or security (Scoones and Forster 2008)?

Recognition of the importance of framing does not imply that scientific rigor carries no value. For any particular framing condition, explicitly disciplined procedures offer important ways to make analysis more systematic, transparent, accountable, reproducible, and (crucially) potentially falsifiable. No matter what variety of framings might be possible, a range of interpretations will typically remain just plain wrong (Stirling 2006a). The issue is, therefore, not that "anything goes," but rather that in complex areas of analysis for policy in fields such as infectious-disease management, reductive–aggregative techniques like risk assessment rarely deliver a single uniquely robust set of findings.

A recognition of the crucial role played by framing holds both negative and positive implications for aspirations toward "evidence-based" decision making in a complex area like avian influenza (Solesbury 2001). On the downside, it undermines any notion that "the evidence" can in any simple way determine some single decision. In reality, evidence typically speaks with many voices, depending on the way it is framed (Shaxson et al., unpublished manuscript). A number of potentially quite radically different decisions may thus be "based on" the same body of scientific information concerning risk.

On the positive side, explicit attention to framing holds out the prospect that framing might itself also be viewed as an intrinsic part of "the evidence." Far from undermining analysis, this reinforces the central thrust of evidence-based decisions as a means to escape from spurious pressures for "evidence-backed" policy (Stirling 2005). Under this latter approach, powerful interests assert their own favored course of action, by deploying particular notions of "evidence," "expertise," or "analysis" to justify decisions that are actually driven by rather different political objectives (Collingridge 1982). By explicitly "mapping" the implications of divergent framings, we provide a counter to these justificatory pressures (Stirling 2008). Thus, through elaborating the consequences

Table 1. A selection of factors influencing the framing of scientific risk assessment.

Setting agendas	Defining problems	Characterizing options
posing questions	prioritizing issues	formulating criteria
deciding context	setting baselines	drawing boundaries
discounting time	choosing methods	including disciplines
handling uncertainties	recruiting expertise	commissioning research
constituting “proof”	exploring sensitivities	interpreting results

of the three core narratives in the international avian influenza response, key trade-offs can be identified, as well as alternative, hidden narratives uncovered (Scoones and Forster 2008).

When sources of variability are made explicit and the link with particular social framings explored, then the resulting picture “bounds” the domain of those priorities and interventions that are accommodated by the evidence and those that are not. No one framing may thus be invoked as exclusively justifying a particular “sound scientific” intervention. An “evidence-bound” approach, in which appraisal “maps” the implications of contending framings thus counters the covert politics of “evidence-backed” approaches (Stirling 2005). It addresses the injunctions of precaution by broadening out the scope of appraisal in the face of incomplete knowledge. By recognizing the importance of subjective values and interests in the interpretation of the evidence, it “opens up” appraisal to participation (Stirling 2008). Taken together, these offer the potential not only for a higher level of analytical rigor (concerning the implications of different framings), but also for enhanced degrees of democratic accountability (allowing for more open allocation of responsibility for decisions). The question is, how might such “mapping” approaches be implemented in real-world policy appraisal in an area like the governance of avian and pandemic influenza?

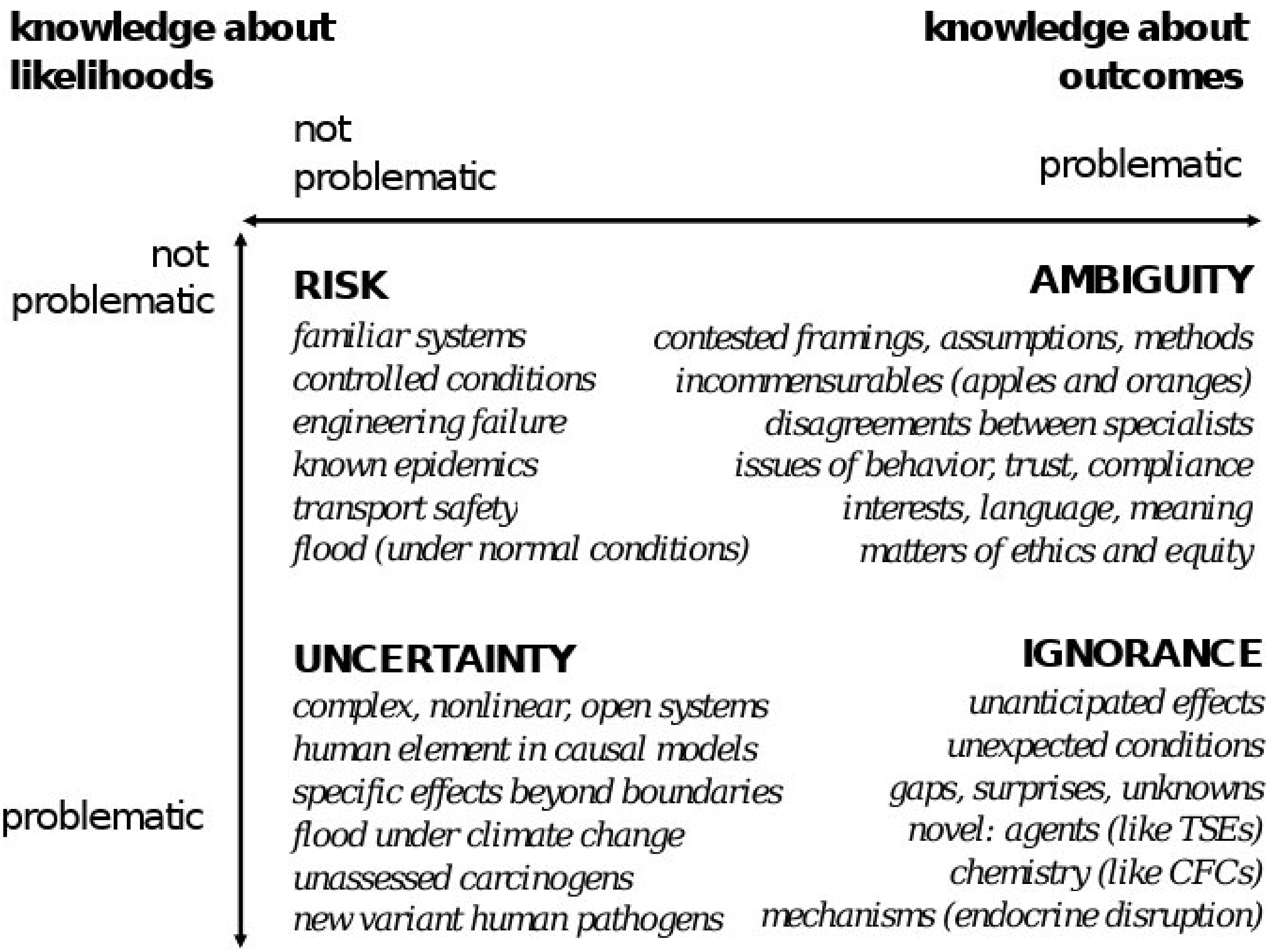
BEYOND RISK ASSESSMENT: MAPPING THE DIMENSIONS OF INCERTITUDE

How, and under what conditions, might a more evidence-bound (mapping) approach be adopted in the policy appraisal of pandemic disease risks, allowing a greater diversity of framings into the picture and affording a greater role for precaution and participation? Perhaps the best way to consider this question is in terms of the same two underlying parameters (probabilities and outcomes) that define the “sound scientific” reductive–aggregative approaches. Each of these two structuring dimensions may be subject to variously incomplete or problematic knowledge. The methodological challenges and their associated responses can then be visualized by considering the resulting four logical permutations of possible states of knowledge shown in Fig. 1 (Stirling 1999).

Various terminologies may be employed for these four contrasting states of knowledge. At the most general of levels, however, Fig. 1 employs terms in a sense that reflects both their colloquial meanings and their strict (and original) technical definitions. To avoid confusion over less-discriminating uses of the words “risk” and “uncertainty,” the term “incertitude” is employed here as a general reciprocal (or antonym) of the term “knowledge,” referring collectively to all four distinct ways in which knowledge may be problematic (Stirling 2003).

However, the crucial point here lies not in the terminology, but in the substance of the distinctions. The four distinguished aspects of incertitude should

Figure 1. Contrasting states of incomplete knowledge, with schematic examples.



knowledge about likelihoods / knowledge about outcomes	not problematic	problematic
not problematic	**RISK** *familiar systems* *controlled conditions* *engineering failure* *known epidemics* *transport safety* *flood (under normal conditions)*	**AMBIGUITY** *contested framings, assumptions, methods* *incommensurables (apples and oranges)* *disagreements between specialists* *issues of behavior, trust, compliance* *interests, language, meaning* *matters of ethics and equity*
problematic	**UNCERTAINTY** *complex, nonlinear, open systems* *human element in causal models* *specific effects beyond boundaries* *flood under climate change* *unassessed carcinogens* *new variant human pathogens*	**IGNORANCE** *unanticipated effects* *unexpected conditions* *gaps, surprises, unknowns* *novel: agents (like TSEs)* *chemistry (like CFCs)* *mechanisms (endocrine disruption)*

not be seen as a taxonomy. They are not discrete or mutually exclusive. Instead, they are "ideal types," reflecting different facets of incomplete knowledge that typically occur together in varying degrees in the management of infectious disease. The purpose of differentiation is, therefore, not to classify cases and instances in the real world, but heuristically to illustrate the diversity of circumstances conventionally rolled together under the term "risk." Each state of knowledge is variously emphasized in different epidemic "narratives" of the kind discussed at the beginning of the paper. In order to substantiate each aspect of incertitude with a view to distinguishing practical responses, Fig. 1 lists examples of empirical areas drawn from broader policy making in which each of these four idealized logically possible states of knowledge may variously come to the fore in policy making.

It is in the top left quadrant that we may confidently rely on the reductive–aggregative ("sound scientific") approaches to risk assessment. It is only here that we may rigorously apply the kind of risk-assessment techniques that are so well established as the norm in disease epidemiology and management. Of course, none of this precludes these methods making appropriately qualified contributions to analysis and decision making under wider circumstances, but the point is that the conditions under which reduction and aggregation can yield definitive groundings for particular "evidence-based" or "sound scientific" decisions are far more restricted than is conventionally recognized to be the case. It is only where relevant past experience or the reliability of scientific models are held to ensure high quality in our knowledge concerning both the different possible outcomes and their respective probabilities, that we can have high confidence in the results yielded by these techniques.

It follows from this that the formal "sound scientific" definition of "risk" also implies less tractable states of "uncertainty," "ambiguity," and "ignorance" (also shown in Fig. 1). These relate equally directly (and rigorously) to the conventional parameterization of the concept of risk itself, but describe a range of circumstances under which application of reductive–aggregative risk-assessment techniques yield enormous (if implicit) variabilities. It is here that the practical methodological implications become quite concrete. Fig. 2 illustrates examples of well-developed but neglected techniques that are well suited to characterizing each of these contrasting aspects of incertitude.

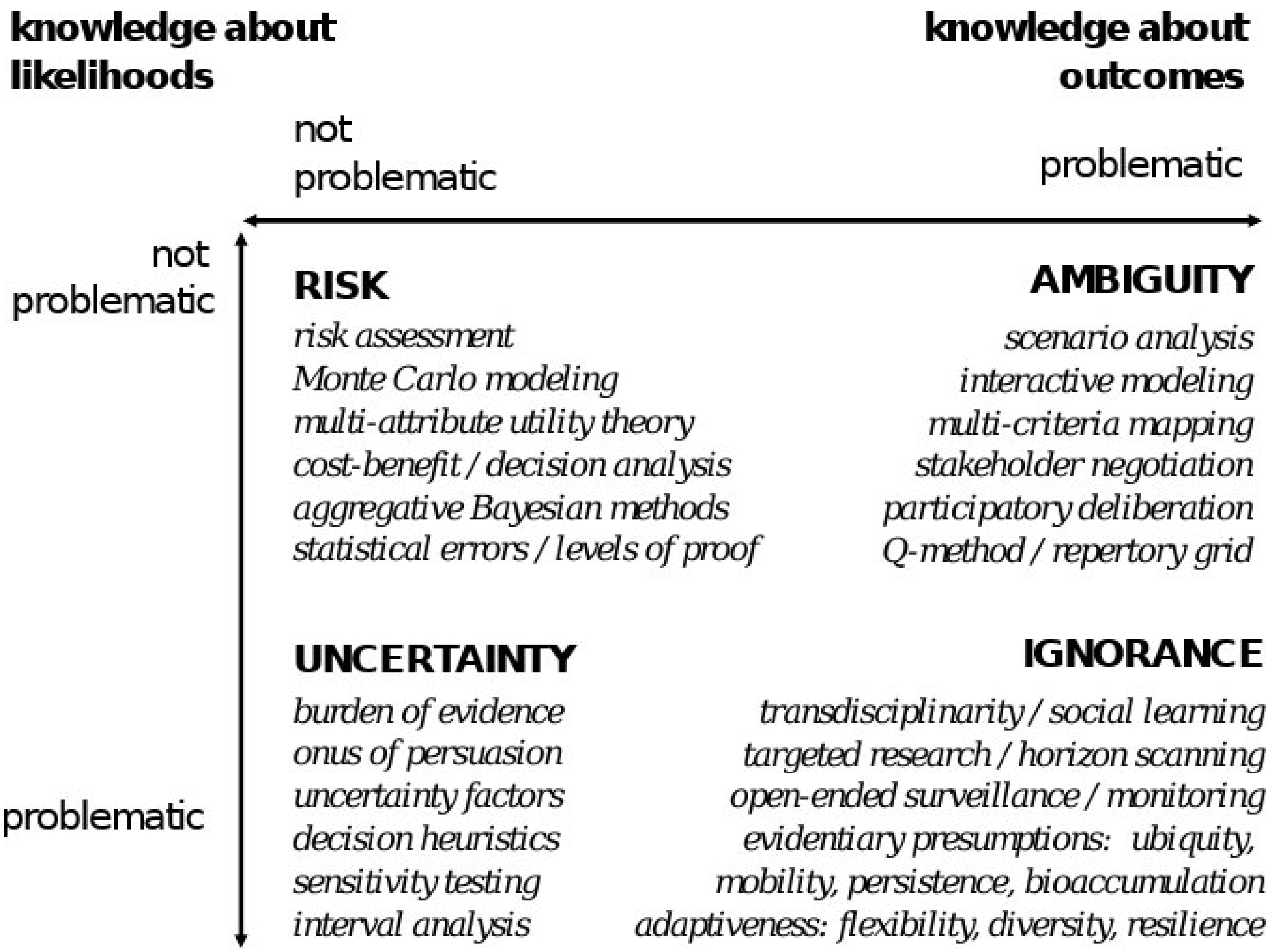
Under the strict definition of "uncertainty" (in the lower left-hand quadrant), we can be confident in our characterization of the different possible outcomes, but the available empirical information or analytical models simply do not present a definitive basis for assigning probabilities (Keynes 1921, Knight 1921, Rowe 1994). It is under these conditions that, in the words of the celebrated probability theorist de Finetti (1974), "probability does not exist." Of course, we can still exercise subjective judgements and treat these as a basis for systematic analysis (Luce and Raiffa 1957, Morgan et al. 1990). However, the challenge of uncertainty is that such judgements may take a number of different, equally plausible forms (Wynne 1992, Stirling 1997).

In the case of avian influenza, for example, the complex, open-ended, nonlinear interactions already noted between the relevant tightly coupled ecological, agronomic, and institutional systems militate strongly against confidence in probabilistic modeling. Quantitative-probabilistic models of course have their place, but they sometimes have undue influence on the policy process, as they present information about outcomes and likelihoods in far more definitive terms than is warranted. In 2005, for example, two models were presented in *Nature* (Ferguson et al. 2005) and *Science* (Longini et al. 2005) that together had a huge influence in framing the response as one that needed to be focused on containment at the source of the outbreak. Yet, contending but equally "sound scientific" or "evidence-based" judgements may also derive from other analyses, more appreciative of complex dynamics and other dimensions of incertitude suggesting alternative policy framings. Thus, for example, the interplay between viral ecology and genetics (e.g., patterns of antigenic shift and drift), transmission mechanisms (e.g., the role of wild birds or poultry, backyard chickens or large factory units) and impacts (e.g., the consequences in immunocompromised individuals and populations) are highly complex and contingent (Scoones and Forster 2008). Rather than reducing this system complexity to a single aggregated value or prescriptive recommendation (as is normal in risk assessment), the prudent and rigorous approach is to acknowledge the variability in possible interpretations (Stirling 2008).

There exists here a range of less ambitious methods than risk assessment. These are nonetheless useful tools that are neglected because of a prevailing preoccupation with risk assessment. They include sensitivity (Saltelli 2001), scenario (Peterson et al. 2003, Werner 2004) and interval analysis (Jaulin et al. 2001), as well as a variety of different "decision heuristics" like the "maximin" or "minimum regret" rules (Forster 1999). What distinguishes these mapping methods is that they acknowledge significant latitude for interpretation. They cannot be used to justify a single apparently definitive "science-based decision," but reveal instead the potentially complementary and tightly integrated roles of precaution and participation.

Under the condition of "ambiguity" (top right quadrant of Figs. 1 and 2), it is not the probabilities, but the characterization of outcomes that is problematic. This may be the case, even for events that are certain or have occurred already. Disagreements may exist, for instance, over the selection, partitioning, bounding, measurement, prioritization, or interpretation of outcomes as part of the narrative framing (Wynne 2002). Examples may be found in decisions over the "right" questions to pose in regulation. In the appraisal of health interventions, even the most narrowly risk-based considerations display some ambiguity over the issues in question. For instance, asking which of a

Figure 2. Methodological responses to different forms of incertitude.



knowledge about likelihoods

knowledge about outcomes

not problematic

problematic

not problematic

problematic

RISK

risk assessment
Monte Carlo modeling
multi-attribute utility theory
cost-benefit / decision analysis
aggregative Bayesian methods
statistical errors / levels of proof

AMBIGUITY

scenario analysis
interactive modeling
multi-criteria mapping
stakeholder negotiation
participatory deliberation
Q-method / repertory grid

UNCERTAINTY

burden of evidence
onus of persuasion
uncertainty factors
decision heuristics
sensitivity testing
interval analysis

IGNORANCE

transdisciplinarity / social learning
targeted research / horizon scanning
open-ended surveillance / monitoring
evidentiary presumptions: ubiquity, mobility, persistence, bioaccumulation
adaptiveness: flexibility, diversity, resilience

series of possible measures would be "safest," "safe," "safe enough," "acceptable," "cost effective," "proportionate," or "best" may each yield radically different answers for risk-based rank orderings of intervention options.

Put simply, these kinds of dilemmas raise the thorny problem of "apples and oranges" in the appraisal of disease-management interventions. Again, these may reflect divergent perceptions not of the likelihoods of different outcomes, but of the structuring, bounding, and partitioning of the intercoupled social, technological, and ecological systems and policy options. More specifically, the challenges arise in comparing different notions of benefit and cost, or different contexts, vectors, or end points of harm. How should we value impacts of disease (or countermeasures) on agricultural workers or the general public; adults or children; affluent or impoverished communities; susceptible genetic subgroups or populations as a whole; domestic citizens or foreigners? All these are implicated in policy making on avian influenza, with often no explicit basis for choice expressed.

When faced with such questions not over uncertainty but "contradictory certainties" (Thompson and Warburton 1985), Nobel Prize-winning work in rational choice theory (Arrow 1963, Kelly 1978, MacKay 1980) has shown that analysis alone is, even in principle, unable to guarantee definitive answers (Collingridge 1982, Bonner 1986). When attention extends to broader values, epistemologies, and ontologies (Leach et al. 2005), then the challenge becomes more complex and intractable. Under a condition of ambiguity (rather than "risk"), then, reduction and aggregation to a single "sound scientific" or discrete "evidence-based" notion of risk is even less rational than under uncertainty.

Again, this does not preclude the use of systematic methods for mapping the dimensions of variability and eliciting the determinants and consequences of different possible perspectives. There also now exists a variety of sophisticated potential appraisal tools. On the quantitative side, these include Q-methodology (McKeown and Thomas 1988), interactive modeling (De Marchi et al. 1998) and "open" forms of multi-criteria appraisal (Stirling 2006b), including "multi-criteria mapping" (Stirling and Mayer 2001). These, in turn, open the door to a host of qualitative approaches to the identification and exploration of contending perspectives (Dryzek 2002, Davies et al. 2003, Burgess et al. 2007). Again, these "mapping" approaches hold open the possibility of much more integrated and complementary relationships between "science-based" methods and more precautionary and participatory appraisal.

Finally, there is the condition of "ignorance." Here we face difficulties in our knowledge of both dimensions of incomplete knowledge, such that neither probabilities nor outcomes can be fully characterized (Keynes 1921, Loasby 1976, Collingridge 1980). Where "we don't know what we don't know" (Wynne 1992, 2002), we face the ever-present prospect of "surprise" (Brooks 1986, Rosenberg 1996). This differs from uncertainty, which can at least in principle be based on agreed, known parameters (like specified pathogens, pathologies, or cost increments). It differs from ambiguity, in that the parameters are not just contestable, undercharacterized, or indeterminate in their relative importance, but are unbounded or partly unknown.

Some of the most important environment and health issues of our time have involved challenges that were, at their outset, a matter of ignorance rather than mere uncertainty or ambiguity (Funtowicz and Ravetz 1990, Faber and Proops 1994). In the early histories of stratospheric ozone depletion (Farman 2001), bovine spongiform encephalopathy (van Zwanenberg and Millstone 2001) and endocrine-disrupting chemicals (Thornton 2000), for instance, the initial problem was not so much divergent expert views or mistakes in estimating probability, but straightforward ignorance over the possibilities. The condition of ignorance has certainly characterized debates over avian and pandemic influenza. No one knows whether human-to-human transmission will arise from the H5N1 virus or not; no one knows whether, if this occurs, it will result in rapid, global transmission with huge mortalities or not. In other words, we are more ignorant than we are uncertain of the characteristics and contextual conditions for the full range of particular mechanisms that might be implicated in this. Likewise, we remain ignorant over the full specification of the precise manner and circumstances under which proposed measures (such as containment, antiviral drugs, or vaccination) will limit the spread of a pandemic in reality.

It is in the nature of surprise that it is intrinsically difficult to substantiate possible examples of ignorance ex ante. Specifically with respect to avian influenza, however, possible surprises may plausibly be anticipated around the emergence of radically new strains of the virus, unexpected transmission mechanisms, or unanticipated health outcomes, including those arising in complex interactions with other health or social conditions. Of course, there is always the broader possibility of the emergence of entirely novel pathogens. Indeed, over 70% of new infectious diseases affecting humans that have emerged over the last 30 years have emerged unexpectedly from nonhuman animal populations (Woolhouse and Gaunt 2007, Jones et al. 2008). As acknowledged in a different context from a rather unexpected source, this is the domain of Donald Rumsfeld"s famous "unknown unknowns" (Rumsfeld 2002). Here, more than anywhere, it is profoundly irrational and unscientific to seek to represent ignorance as risk.

Yet, even here, there are many practical things that can be done, and that undue preoccupation with risk assessment can obscure (Klinke et al. 1999, EEA 2001). The imperative to "map" (rather than aggregate) possibilities is especially strong. Some examples of methods that are already well practiced include a shift of emphasis from modeling to real-world, field-based monitoring and surveillance based on the diverse knowledge of particular disease contexts (Calain 2007), the undertaking of more actively targeted scientific research, particularly focusing on the underlying ecological, social, and economic drivers of emergent diseases (Slingenbergh et al. 2004, Parkes et al. 2005), and the prioritizing of methods like horizon scanning and an emphasis on "adaptive management" in governance strategies (Wilcox and Colwell 2005, Voss et al. 2006). In general terms, this might include a more serious role for the appraisal of properties like reversibility, flexibility, and diversity in contending policy instruments (Stirling 2008). It is only when there is appreciation for "what we don't know, we don't know" that we see the real value in the exercise of greater humility in prescription, intervention, and governance of disease control and management.

The key point summarized in Figs. 1 and 2 is that the indeterminacies of uncertainty, ambiguity, and ignorance are intrinsic to the scientific definition of risk. Their recognition should thus be regarded as a necessary feature of scientific understanding, rather than of some external, critical perspective. There is nothing about this view that precludes acknowledgement that conventional reductive–aggregative techniques offer a powerful suite of methods under a strict state of risk. The point is, however, that these conventional risk-assessment techniques are quite simply not applicable under conditions of uncertainty, ambiguity, and ignorance. Although attempts are sometimes made to downplay these distinctions through expedient use of terminology, the underlying substantive challenges are not so easily dismissed.

Contrary to received narrow notions of "science-based" risk assessment, then, persistent adherence to the sufficiency of reductive–aggregative methods under conditions other than the strict state of risk are irrational, unscientific, and potentially highly misleading. Instead, there exist a wide range of "mapping" methods that do not seek to reduce and aggregate the complexities to derive apparently simple, but misleading, unitary prescriptions for policy making. These are more open to a substantive role from participatory engagement and are more explicit and systematic about the scope for normative principles such as precaution. We argue that it is these methods that require urgent attention in the governance of pandemic threats from avian influenza.

BROADENING AND OPENING UP APPRAISAL WITH PRECAUTION AND PARTICIPATION

We began by outlining a series of criticisms conventionally leveled at calls for greater roles for precaution and participation in the policy appraisal of risks, such as those presented by avian and pandemic influenza. In particular, a well-established range of reductive–aggregative risk-assessment techniques are widely referred to as presenting more "sound scientific" and "evidence-based" approaches to policy appraisal. In particular, risk assessment is argued to be more rigorous, complete, and robust than are the procedures associated with either precaution or participation. It is on this basis that worldwide policy making on avian and pandemic influenza is disproportionately preoccupied by these kinds of appraisal methods.

To recap, risk assessment is argued to be more rigorous, because rather than being driven by subjective anxieties over possible harm, it applies clear decision rules objectively to weigh different risks against each other (and associated benefits). Risk assessment is also viewed as more complete in scope than precaution or participation, because the specialist expertise on which it relies provides a more extensive and balanced basis for addressing the range of different dimensions of risk. Finally, risk assessment is conventionally assumed to deliver more robust results than either precaution or participation, in that the outcomes present a more precise and accurate grounding for concrete policy interventions. These may seem relatively uncontroversial positions. But, simply stated, it follows from the preceding sections of our work that each of these claims (and associated criticisms) is false. We will conclude this section by revisiting each of these main themes in turn.

Reductive–aggregative risk assessment can certainly be seen as rigorous. But this is only within the narrow confines of applicability of particular reductive–aggregative procedures. There is too little attention to the boundary conditions inherent in these methods. Indeed, far from being a relatively tractable matter of "risk," complex, dynamic, distributed challenges like threats from avian and pandemic influenza are often better understood as conditions of uncertainty, ambiguity, and ignorance. It is a crucial contribution of precaution that it directs attention to the many kinds of more intractable ways in which knowledge can be lacking.

A diverse array of mapping approaches (discussed in the last section and summarized in Fig. 2) present more systematic means to acknowledge, explore, and characterize the inherent indeterminacies of policy appraisal. It is in conjunction with these mapping approaches that we can also appreciate a key value of more participatory frameworks for policy appraisal. Although technical analysis remains a legitimate matter for specialist expertise, the systematic "opening up" to divergent publics, values, priorities, and meanings presents the only way rigorously to validate the range of contrasting framing conditions typically displayed in appraisal under uncertainty, ambiguity, and ignorance. This is as much the case with respect to avian and pandemic influenza risks as it is in the other areas of policy appraisal. Thus, for example, more effective surveillance (and so, response) emerges with greater engagement of local people and local knowledge about disease contexts and ecologies. Opening up the range of knowledge inputs under conditions of uncertainty, ambiguity, and ignorance reduces the negative consequences of surprise and prevents a dangerous narrowing of disease management and control options (Scoones and Forster 2008).

Turning next to concerns over "completeness," it is true that risk assessment (in all its forms) does offer elegant means for systematically articulating a wide variety of different issues and specialisms. This is especially attractive in a field like avian influenza, which requires attention to highly complex and dynamic interactions among diverse ecological, technological, and social systems. However, we have seen that the apparent completeness of risk assessment is compromised by the essential role played by narrow utilitarian assumptions over the inherent rationality of trade-offs between contending criteria. This can constrain the kind of ethical issue or perspective that is able to be considered. It also restricts the accessibility of appraisal to those (expert) perspectives for whom this normative framework is most reasonable. Moreover, the emphasis on formal calculative procedures of reduction and aggregation in practice forces a further simplification of attention and narrowing of scope. As a result, there is a disproportionate focus on the most direct, linear, and readily quantified effects. This is a rather dangerous feature in policy appraisal, where (as in the case of avian influenza) some of the most important threats arise from the most complicated synergies, nonlinear interactions, and unquantifiable factors.

A key feature of precaution in this regard is not just the simple normative injunction found in the precautionary principle (reviewed earlier), but the stimulus this presents toward more broad-based appraisal processes (Stirling 2006a, 2009). This frees policy appraisal from the necessity to perform narrow reductive–aggregative calculations in order to justify ostensibly definitive–prescriptive results. Instead, appraisal can proceed with greater humility to consider a wider range of less readily tractable aspects. It is in this sense that "broad-based" precautionary appraisal (again using the mapping techniques highlighted in Fig. 2) may be seen to offer greater completeness, in particular by opening the door to more meaningful participation. It is only in this way that attention can be extended away from the privileging of the subjective values and priorities of expert communities, and accommodate, instead, the broader framings found in wider social perspectives. Thus, in the context of avian and pandemic influenza, by moving beyond the "outbreak narratives" offered by veterinarians, public-health professionals, and emergency-response agencies, alternative policy narratives may emerge based on different framings of problems and solutions. For example, with a normative focus on poverty reduction, social justice, and development, some of the responses to avian influenza in poorer communities may be considered. New questions may be asked, and new objectives set. Is it appropriate to propose mass culling of poultry if these are the only source of livelihood of the poorest? What would "market restructuring" look like if a poverty-reduction and social-justice focus was added to the imperative of biosecurity? Similarly, a focus on rights, access, and equity in global responses to avian influenza may also suggest a different set of framings, suggesting some alternative policy narratives (Farmer 1996). The standard global response has been seen as one based on the "global public good." But which public, where? Under conditions of a pandemic outbreak of rapidly spreading and highly pathogenic influenza, who would have access to vaccines and drugs, who would be subject to draconian containment measures, and who would suffer the highest mortalities? Questions of distribution, rights, and political economy come to the fore.

These are questions that are often obscured by the more technical, universal outbreak-narrative framings which have dominated the debate so far (Scoones and Forster 2008).

Finally, there are questions over whether precautionary and participatory mapping methods are less robust as a basis for policy making than risk assessment. It is easy to see why such concerns should arise. Reductive–aggregative risk-assessment techniques are distinguished by their emphasis on unitary quantitative outputs that appear to yield neat prescriptive justifications for decision making (Stirling 2008). Where attention is restricted (ex ante) to the ostensibly precise findings obtained under particular framings, this can certainly look robust. It is only when attention extends (often ex post) to the full range of possible parallel findings associated with different framings that this robustness looks fragile. In other words, concerns over the robustness of broad-based precaution and more open forms of participation are based on a fallacious conflation of accuracy and precision. Just because risk-assessment results are often more precise than more broad and open "mapping techniques" does not mean that they are any more accurate. Indeed, there is a crucial deeper connotation of robustness under which exactly the opposite is true. It is only in the representation of the full envelope of possible equally reasonable interpretations that we can truly hope to find accuracy. The explicit variability documented in mapping results allows for explicit attention to the conditions attached to a plurality of equally reasonable framings of the available science and evidence. In this way, policy appraisal presented as plural and conditional findings of a mapping exercise is actually a more robust picture of the implications of different possible framings. On these grounds, it is the more modest mapping techniques shown in Fig. 2, in conjunction with broad-based precautionary appraisal processes involving open-ended participatory engagement that may truly claim to provide a more robust basis than conventional reductive–aggregative risk assessment for policy making.

In the case of policy making surrounding avian and pandemic influenza, a set of cognitive, professional, cultural, and institutional factors have, to date, prevented such a broadening and opening up to occur. This has resulted in a strong tendency toward narrow framings, focused on combinations of the three outbreak narratives outlined earlier, often based on reductive–aggregative analyses (Scoones and Forster 2008). These have led to a particular set of responses, excluding other alternatives which, arguably, offer a better (more rigorous, complete, and robust) set of responses to existing risks and potential threats. A failure to adopt a more open, participatory, and precautionary stance in appraisal and policy response has narrowed options and constrained policy thinking. If the international response to avian and pandemic influenza (and indeed policies and programs associated with other emerging infectious diseases) is to move forward, a more comprehensive appreciation of the dimensions of incertitude is essential.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol14/iss2/art14/responses/

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