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Andrew Barry, Georgina Born and Gisa Weszkalnys

Abstract

This paper interrogates influential contemporary accounts of interdisciplinarity, in which it is portrayed as offering new ways of rendering science accountable to society and/or of forging closer relations between scientific research and innovation. The basis of the paper is an eighteen-month empirical study of three interdisciplinary fields that cross the boundaries between the natural sciences or engineering, on the one hand, and the social sciences or arts, on the other. The fields are: 1) environmental and climate change research, 2) ethnography in the IT industry and 3) art-science. In the first part of the paper, in contrast to existing accounts, we question the idea that interdisciplinarity should be understood in terms of the synthesis of two or more disciplines. We stress the forms of agonism and antagonism that often characterize relations between disciplinary and interdisciplinary research, and distinguish between three modes of interdisciplinarity. In the second part we outline three distinctive logics or rationales that guide interdisciplinary research. In addition to the logics of accountability and innovation, we identify the logic of ontology, that is, an orientation apparent in diverse interdisciplinary practices in each of our three fields towards effecting ontological transformation in the objects and relations of research. While the three logics are interdependent, they are not reducible to each other and are differently entangled in each of the fields. We point to the potential for invention in such interdisciplinary practices and, against the equation of disciplinary research with autonomy, to the possibility of forms of *inter*disciplinary autonomy.

Keywords: interdisciplinarity; interdisciplinary research; accountability; innovation; ontology; ethnography; environment; art-science.

Disciplines and interdisciplines

The idea of discipline opens up a nexus of meaning. Disciplines discipline disciples. A commitment to a discipline is a way of ensuring that certain

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disciplinary methods and concepts are used rigorously and that undisciplined and undisciplinary objects, methods and concepts are ruled out. By contrast, ideas of interdisciplinarity and transdisciplinarity imply a variety of boundary transgressions, in which the disciplinary and disciplining rules, trainings and subjectivities given by existing knowledge corpuses are put aside or superseded. In this paper we interrogate the current preoccupation with interdisciplinarity, in particular the ascendance in recent years of a particular discourse on interdisciplinarity where it is associated with a more generalized transformation in the relations between science, technology and society. We are therefore less concerned with interdisciplinarity in general than with the contemporary formation of interdisciplinarity, how it has come to be seen as a solution to a series of contemporary problems, in particular the relations between science and society, the development of accountability and the need to foster innovation in the knowledge economy. The present situation can be understood as a problematization: the question of whether a given knowledge practice is too disciplinary, or interdisciplinary, or not disciplinary enough has become an issue and an object of enquiry for governments, funding agencies and researchers themselves.

Exemplary of this problematization was the publication by Helga Nowotny, Peter Scott and Michael Gibbons of *Re-Thinking Science* in 2001. Nowotny and her collaborators suggest that the concern with interdisciplinarity is part of a shift from what they call Mode-1 science to Mode-2 knowledge production (Gibbons *et al*., 1994; Nowotny, Scott, & Gibbons, 2001). The latter is said to include: the growth of transdisciplinary research which 'transcends disciplinary boundaries' (Nowotny *et al*., 2001, p. 89); the development of novel forms of quality control which undermine disciplinary forms of evaluation; the displacement of a 'culture of autonomy of science' by a 'culture of accountability' (Nowotny, 2003, pp. 211–12); the growing importance of the 'context of application' as a site for research; and a growing diversity of sites at which knowledge is produced. In a recent on-line forum on interdisciplinarity Nowotny reiterated these views:

> We introduced the idea of Mode-2 in order to bring in a new way of thinking about science, which is often described in strictly disciplinary terms. We identified some attributes of the new mode of knowledge production, which we think are empirically evident, and argued that, all together, they are integral or coherent enough to constitute something of a new form of production of knowledge.
>
> (Nowotny, n.d., p. 2)

Other commentators broadly concur with this account. Researchers from the Interdisciplinary Studies Project at Harvard University, for example, note that there is a 're-emerging awareness of interdisciplinarity as a pervasive form of knowledge production' (Mansilla and Gardner, n.d., p. 1), while a major study concerned with interdisciplinary research sponsored by the US National Academies declares that 'as a mode of discovery and education, [interdisciplinary research] has delivered much already and promises more – sustainable

environment, healthier and more prosperous lives, new discoveries and technologies to inspire young minds, and deeper understanding of our place in space and time' (National Academies, 2005, p. 1). Assertions of a link between interdisciplinarity and accountable science responsive to user needs can also be found in the US Gulbenkian Commission's report on the restructuring of the social sciences (Wallerstein, 1996) and the 2000 report of the German Science Council. In the UK, a recent paper by HM Treasury suggests that interdisciplinarity should lie at the heart of the government's research strategy: 'In order to maintain the UK's world-class university system, the [g]overnment is keen to ensure that excellent research of all types is rewarded, including user-focused and interdisciplinary research' (HM Treasury, 2006). For the Treasury, interdisciplinarity releases research from the restrictions of disciplinary boundaries (Weingart & Stehr, 2000, p. 270) and in so doing enables it to be more readily connected to the needs of industrial users and market demands.

Two inflections of the discourse on interdisciplinarity are particularly apparent in these analyses and policy documents. The first portrays interdisciplinarity as offering new techniques for accountability or even as itself an index of accountability (Strathern, 2004). The second lays emphasis on the capacity of interdisciplinarity to assist in forging closer relations between scientific research and the business of innovation (Nowotny, 2005). In this way it is envisaged that science will be further integrated into the knowledge economy (Lowe & Phillipson, 2006; Strathern, 2006). In contrast, disciplinarity is associated with a defence of academic autonomy.

In this paper we discuss the results of an eighteen-month comparative empirical study of interdisciplinary research institutions and initiatives.[1] Our study focused on those forms of interdisciplinarity that cut across the boundaries between the natural sciences or engineering, on the one hand, and the social sciences, humanities or arts, on the other. It is these kinds of interdisciplinary research that are thought to have greatest significance in the transition to a new mode of knowledge production, auguring closer relations between science and society.[2] Throughout the paper we use 'interdisciplinary research' primarily to refer to these specific interdisciplinary forms. The paper has two parts. In the first we examine the different types of relations that can exist between disciplines. We question the idea that interdisciplinarity should be understood simply in terms of the synthesis of two or more disciplines. We stress the importance of attending to the kinds of agonism and antagonism that often characterize relations between disciplinary and interdisciplinary research, and distinguish between three *modes* of interdisciplinarity. In the second part we identify three distinctive *logics* or rationales that motivate interdisciplinary research, which we term the logics of accountability, innovation and ontology. Our classifications are meant to be neither exhaustive nor definitive; they are intended to demonstrate the limitations of those accounts that portray interdisciplinarity exclusively or primarily as a synthesis, or in terms of its connections with accountability or innovation.

Our empirical research had two elements. The first was an internet-based mapping survey of interdisciplinary fields, which enabled us to develop an initial typology of forms of interdisciplinarity and to identify three significant and developing interdisciplinary fields, namely: 1) environmental and climate change research, 2) ethnography in the IT industry, and 3) art-science (Weszkalnys, 2006). We then carried out ten case studies of interdisciplinary institutions and initiatives across the three fields in different national settings.[3] We do not suggest that the institutions chosen are typical, but that they are symptomatic – that is, influential and potentially inventive in their respective fields (Born, forthcoming). In other writings we give an analysis of each field and of specific institutions in greater detail.

In carrying out the research we wanted to avoid two temptations. The first is to imagine that interdisciplinarity is historically novel – that in the past knowledge production has primarily taken place within autonomous unified disciplines and that it no longer does so (*Social Epistemology,* 1995; Galison & Stump, 1996; Weingart & Stehr, 2000). Without doubt, knowledge production has always occurred in a variety of institutional sites and geographically dispersed assemblages, not just in the apparently enclosed space of the humanist's study or the scientific laboratory (Livingstone, 2003; Osborne, 2004). Moreover, the evolution of disciplines has often come about through the eruption of interdisciplinary challenges. Even an apparently pure discipline such as astronomy has been transformed historically through the emergence of new forms of interdisciplinary knowledge and practice which struggle for visibility with existing norms and are subsequently accepted into the corpus (Schaffer, 2007). In other cases what were once interdisciplines themselves become progressively established as distinct fields or disciplines. If the appearance of interdisciplinarity is a historical constant, then, what is novel is the contemporary sense that greater interdisciplinarity is a necessary response to intensifying demands that research should be integrated with society and the economy.[4]

Second, and relatedly, there is a temptation to read the contemporary concern with interdisciplinarity too politically in the conventional sense of the term: to view it as entirely an emanation from governmental preoccupations with accountability, the knowledge economy or innovation, or as driven by commercial imperatives. Here, the temptation is to unify interdisciplinarity excessively. Others have rightly pointed to the force of these dynamics, as noted above (Mirowski & Mirjam Sent, 2002); and interdisciplinarity has certainly become a key term in the government of research, evident in efforts to transform the relations between research, economy and society (Strathern, 2006; cf. Power, 1996). Yet it is critical to recognize that these developments coexist with other dynamics, and in particular that the current range of concerns with interdisciplinarity does not necessarily lead to a reduction in the autonomy of research. As we shall argue, interdisciplinarity can be associated with the development of fields and initiatives in which new kinds of autonomy are defended against a reduction of research to questions of accountability or

innovation. It can generate knowledge practices and forms, and may have effects, that cannot be understood merely as instrumental, or as responses to broader political demands or social and economic transformations. In short, autonomy may be associated as much with interdisciplinary as with disciplinary research.

In light of these temptations, our starting point in the study was a dissatisfaction with the teleological and unitary account of interdisciplinarity in much of the literature. Nowotny *et al.*'s depiction of interdisciplinarity is persuasive and has been highly influential as a political intervention. During our research, we found that the narrative of 'Mode-2' was not only echoed in current assessments of research policy and practice (e.g. Century, 1999; Becker, 2003), but had become performative: folded into the research institutions and practices that we were studying and even offered by some interviewees as a 'local' framework of understanding. Rather than accept this framing we strove to get a sense of the multiplicity of interdisciplinary forms and their diverse histories, to treat interdisciplinarity as unified – through a series of interrelated policy initiatives and analyses – but also as heterogeneous, evident in the proliferation of a variety of interdisciplinary fields, institutions and experiments and the specificity of their trajectories. In this way the study confronted a series of problems: how can we give any coherence to the arguments linked by the notion of interdisciplinarity, and what other unities might be revealed that are not immediately apparent? Why should we think that there is a discontinuity in the mode of production of knowledge, and what other 'differences, relations, gaps, shifts, independences, autonomies' might be occluded by such a claim (Foucault, 1972, p. 191)? In short, how might one understand interdisciplinarity less as a unity and more as a space of differences, a multiplicity?

In what follows we treat notions of accountability and innovation as part of the local frameworks through which policy-makers and researchers implicitly or explicitly rationalize the importance and function of interdisciplinary research. Drawing on Tarde's theorization of imitation and invention, we take accountability and innovation to be logics: that is, a set of contemporary rationales about what the purposes of interdisciplinarity are and how it should be guided and justified (Tarde, 2001, ch. 5; Barry & Thrift, 2007). In writing of the logic of accountability we refer to a range of ways in which scientific research is increasingly expected to be accountable to society. By the logic of innovation we refer to a spectrum of arguments about how scientific research can be expected to contribute to industrial innovation and economic growth. This reasoning has a long history stretching back to at least the mid-nineteenth century. However, in recent years the logic of innovation has acquired a particular intensity and form (Barry, 2001, ch. 1). One characteristic of the contemporary inflection of this logic is the increasing importance given to the social sciences in fostering links between scientific and technological development and the market. In this way the social sciences have become part of the

rapidly evolving knowledge base of contemporary capitalism (Jessop, 2005; Thrift, 2005).

These logics may be articulated by different institutions and persons with radically different implications and effects. In some instances, for example, the claim that interdisciplinarity renders research more accountable may simply serve to legitimize existing forms of research practice. In other cases there may be a much stronger link between the logics and transformations in research practice. Yet the practices of interdisciplinarity may be only partially governed by these logics. Moreover, the outcomes of interdisciplinary research will variably fulfil the rationales.

At the same time, we argue that interdisciplinary research can be guided by other logics, in particular by what we term the logic of ontology. With this analysis we highlight how the forms of interdisciplinary research addressed by our project have been explicitly or implicitly driven not only by the rationales of fostering accountability or innovation, but by an orientation towards effecting ontological change. This may be manifest, as we will show, in intentions to re-conceive both the object(s) of research and the relations between research subjects and objects.[5] One of the intended consequences of some kinds of ethnographic research in the IT industry, for example, is to create new forms of technical object that are recognized as at once socially and culturally embedded. One goal of some art–science initiatives is not so much to render art or science more accountable, but to challenge and transform existing ways of thinking about the nature of art and science, as well as the relations between artists and scientists and their objects and publics.

In distinguishing between these logics we wish to make two further points. First, the logics of interdisciplinarity that we describe here can be interdependent. They may also be elided; it is notable, for instance, that concepts of 'users' and 'user needs' have migrated so that they are now taken to encompass not only responsiveness to industry or consumers but accountability to publics (Strathern, 2004). Our aim in identifying the three logics is to indicate how they are mutually imbricated in the interdisciplinary fields that we studied. If accountability and innovation are invariably linked to the contemporary discourse on interdisciplinarity, in what follows our focus is their heterogeneous expression in these fields and how they are entangled with the logic of ontology. Second, we do not imply that our analysis is exhaustive. It would be possible to multiply the number of logics governing the development of interdisciplinarity and to attend to a series of further differences (Tait & Lyall, 2001, p. 8). Nor do we imply that interdisciplinary research has always been guided by these rationales. Rather, our scheme aims to render visible the ways in which the ontological logic of interdisciplinarity is both irreducible to the logics of innovation and accountability and yet also entangled with them.

In drawing attention to the multiple logics of interdisciplinarity, and in contrast to the teleology of other accounts, we want to argue that interdisciplinary research has the potential to be inventive. The notion of

invention points to the openness of the contemporary historical situation (Feltham & Clemens, 2003, 27). An invention can be understood as the introduction of a type of novelty into a particular domain, one that cannot be explained away as the consequence of pre-existing factors or forces, and which serves to protend and open up the space of future possibilities (Barry, 2001; Born, 2005). Thus, while the call for interdisciplinarity today is often understood in terms of the needs of stakeholders or the demands of the economy, interdisciplinary research may lead to forms of novelty which cannot be assumed to follow from governmental demands or from any given historical logic. In referring to the notion of invention, then, we point to a central concern of this paper. Rather than identify a new stage in the production of knowledge, one of our aims is to heighten awareness of what is potentially inventive in the present burgeoning of interdisciplinarity in particular fields.

Modes of interdisciplinarity

Much of the heat manifest in debates about interdisciplinarity stems from the potential for polarized judgements about the creative or repressive status of disciplinary knowledge. On one side are those for whom disciplines are generative and enabling, the repositories of a responsible kind of epistemological reflexivity. Marilyn Strathern gives voice to such a perspective when she writes that 'the value of a discipline is precisely in its ability to account for its conditions of existence and thus ... how it arrives at its knowledge practices' (2004, p. 5). On the other side are those who see disciplines as 'inherently conventional', 'artificial "holding patterns" of inquiry' sustained by historical casts of mind 'that cannot imagine any alternatives to the current [disciplinary] regime'. In this view the significance of interdisciplinary research lies in the contrast with what are taken to be the more restrictive structures of disciplinary knowledge. Only interdisciplinarity holds out the promise of 'sustained epistemic change' (Fuller, 1993, n.d., pp. 1, 4).

In thinking about the relations between disciplinarity and interdisciplinarity, however, it would be a mistake to contrast the homogeneity and closure of disciplines with the heterogeneity and openness of interdisciplinarity. On the one hand, interdisciplinary research can involve hypostatization and closure, limiting as well as transforming the possibility for new forms, methods and sites of research (Weingart & Stehr, 2000; Strathern, forthcoming). On the other hand, disciplines themselves are often remarkably heterogeneous or internally divided (Galison, 1996b; Bensaude-Vincent & Stengers, 1996). Consider, for example, the differences between theoretical and experimental high-energy physics (Knorr Cetina, 1999) or between computational and laboratory medicinal chemistry (Barry, 2005). Even more radical internal differences exist between physical and human geography (Harrison *et al.*, 2004) and between the sub-disciplines of anthropology (Lederman, 2005). Indeed, disciplines are routinely characterized by internal differences; the

existence of a discipline does not always imply the acceptance of an agreed set of problems, objects, practices, theories or methods, or even of a shared language or common institutional structures.

Yet this heterogeneity is not necessarily a source of instability. In one account, 'the disunified, heterogeneous assemblage of the subcultures of science is precisely what structures its strength and coherence' (Galison, 1996a, p. 13). Disciplines exhibit clear inertial tendencies, and differences within them may exist over long periods of time. They may develop ways of translating across and negotiating internal boundaries; or chronic internal intellectual divisions may persist unaddressed through pragmatic working arrangements, or may even be collectively denied. Disciplines should not therefore be regarded as homogeneous, but as multiplicities or heterogeneous unities marked by differences which are themselves enacted in multiple ways (cf. Laclau & Mouffe, 1985, p. 96). The existence of a discipline does imply a historically evolving and heterogeneous nexus of objects, problems, theories, texts, methods and institutions that are thought to be worth both contesting and defending. The boundaries of a discipline and the form in which it should exist, then, are in question and in play. Disciplinary boundaries and contents are neither entirely fixed nor fluid; rather, they are relational and in formation – dynamics captured by Stefan Collini in a powerful metaphor when discussing the emergence of cultural studies from its disciplinary progenitors: 'Cultural studies is part of the noise made by the great academic ice-floes of Literature, Sociology and Anthropology ... as their mass shifts and breaks apart' (1994, p. 3).

Further conceptual ground-clearing is necessary in the face of efforts to define three types of cross-disciplinary practice: interdisciplinarity, multidisciplinarity and transdisciplinarity. Commonly, a distinction is made between multidisciplinarity – in which several disciplines cooperate but remain unchanged, working with standard disciplinary framings – and interdisciplinarity – in which there is an attempt to integrate or synthesize perspectives from several disciplines.[6] Ian Hacking, for instance, sets out the case for multidisciplinarity when he argues for 'collaborating disciplines that need not be interdisciplinary' and that presume a strong disciplinary base in the study of complex objects (Hacking, n.d.). Transdisciplinarity, in contrast, is taken to involve a transgression against or transcendence of disciplinary norms, whether in the pursuit of a fusion of disciplines, an approach oriented to complexity or real-world problem-solving, or one aimed at overcoming the distance between specialized and lay knowledges or between research and policy or 'decision-making in society' (Lawrence & Després, 2004, pp. 398–400). Transdisciplinarity is the term favoured by Nowotny *et al*. for the Mode-2 knowledge production characteristic of what they term a 'Knowledge Society': thus, '[i]ts reflexivity, eclecticism and contextualization mean that Mode-2 knowledge is inherently transgressive. ... [It] transcends disciplinary boundaries. It reaches beyond interdisciplinarity to transdisciplinarity' (Nowotny *et al*., 2001, p. 89). Whatever their descriptive uses, in general

these definitional efforts have not proven generative in analytical terms. As Petts, Owens, & Bulkeley (in press, p. 8) note, the various definitions point to a spectrum: 'at its weakest, interdisciplinarity constitutes barely more than cooperation, while at its strongest, it lays the foundation for a more transformative recasting of disciplines.' We therefore take 'interdisciplinarity' as a generic term for this spectrum, while signalling salient issues from the definitional debate as they arise in our analysis.

How then can we conceptualize the relations between disciplinary and interdisciplinary forms of knowledge? Previous policy interventions and theoretical literatures on interdisciplinarity have tended to assume an *integrative* or *synthesis* model of interdisciplinarity, in which the interdisciplinary field is conceived in terms of the integration of two or more 'antecedent disciplines' in relatively symmetrical form (Tait & Lyall, 2001; Ramadier, 2004; National Academies, 2005, p. 26; Mansilla, 2006; Nowotny, n.d.). A major recent study of interdisciplinarity articulates this position clearly:

> In this integrative approach it is proposed that interdisciplinary work should be judged according to the criteria of the 'antecedent disciplines' and the value will be assessed in terms of these additive criteria. ... In this study we defined 'interdisciplinary work' as work that integrates knowledge and modes of thinking from two or more disciplines. Such work embraces the goal of advancing understanding (eg explain phenomena, craft solutions, raise new questions) in ways that would have not been possible through single disciplinary means.
>
> (Mansilla & Gardner, n.d., p. 1)

This model has been performative. In climate change research, for example, it is thought that natural scientific and social scientific accounts of impacts might be integrated into a more general model, with social scientists providing an account of social factors ('society', 'the economy') which impact on climate change and are in turn impacted on by climate change (Jasanoff & Wynne, 1998, p. 3). The development of mathematical models provides one way in which such a synthesis can be achieved. It is worth noting, however, that, far from leading to the formation of new heterogeneous fields, the development of increasingly 'universal' models can lead to new kinds of closure effected through synthesis (Bowker, 1993). While the integrative mode can augur epistemic change, then, it does not guarantee it.

In our view, interdisciplinarity should not necessarily be understood additively as the sum of two or more disciplinary components or as achieved through a synthesis of different approaches. If we take the *integrative-synthesis* mode as a first type, we want to propose two additional ideal-typical modes of interdisciplinarity, both of which figure prominently in our research and which may coexist in some fields. In the second, *subordination-service* mode, one or more disciplines are organized in a relation of subordination or service to other component disciplines. This points to the hierarchical division of labour that

characterizes many kinds of interdisciplinarity, an arrangement that may favour the stability and boundedness of component disciplines and inhibit epistemic change. In this mode the service discipline(s) is commonly understood to be making up for or filling in for an absence or lack in the other, (master) discipline(s). In some accounts the social sciences are understood precisely in these terms. They appear to make it possible for the natural sciences and engineering to engage with 'social factors' which had hitherto been excluded from analysis or consideration. Social scientists are expected to 'adopt the "correct" natural science definition of an environmental problem "and devise relevant solution strategies"' (Leroy, 1995, quoted in Owens, 2000, p. 1143, n. 3); or they may be called upon to assess and help to correct a lack of public understanding of science (Irwin & Wynne, 1996). One of the key justifications for funding art-science, particularly in the UK, has been the notion that the arts can provide a service to science, rendering it more popular or accessible to the lay public or publicizing and enhancing the aesthetic aspects of scientific imagery. Ironically, our research suggests that, in the microsocial space of interdisciplinary practice, the hierarchy entailed in the subordination-service mode can be inverted. In art-science, scientists sometimes adopt a service role for artist collaborators, providing resources and equipment to further a project conceived largely in artistic terms (cf. Born, 1995), while in the IT industry engineers may be called into the service of ethnographers.

In the third, *agonistic-antagonistic* mode, in contrast, interdisciplinary research is conceived neither as a synthesis nor in terms of a disciplinary division of labour, but as driven by an agonistic or antagonistic relation to existing forms of disciplinary knowledge and practice. Here, interdisciplinarity springs from a self-conscious dialogue with, criticism of or opposition to the intellectual, ethical or political limits of established disciplines or the status of academic research in general – a transposition on the plane of the politics of knowledge of Mouffe's (2005) stress on antagonism as constitutive of the political. This does not mean that what is produced can be reduced to these antagonisms. Through this mode we highlight how this kind of interdisciplinary field or practice commonly stems from a commitment or desire to contest or transcend the given epistemological and ontological assumptions of historical disciplines – a move that makes the new interdiscipline irreducible to its 'antecedent disciplines'.[7] We will show, for example, how certain advocates of ethnography in the IT industry seek explicitly to constitute ethnography as a field which may be intellectually antagonistic both to existing sociological approaches to the study of technology (Randall, Harper, & Rouncefield, 2005) and to narrowly scientific and technical understandings of the properties and uses of technical objects and devices (Suchman, 1987; Nardi, 1996; Dourish, 2001).

Prominent in discussions of interdisciplinarity are two further methodological orientations which span the three modes. On the one hand, interdisciplinarity is commonly identified with problem-solving in response to new problems or objects that, it is believed, lie beyond the frame of existing

disciplines. But rather than conceive of problems arising *de novo* and demanding interdisciplinary solutions, we should understand them as constituted as interdisciplinary problems relationally through dialogue or dissatisfaction with the problematics proffered by existing disciplines and institutions. The problem-focused, policy orientation of interdisciplinary environmental research, for instance, developed in conjunction with the constitution of multi-dimensional practical and political issues such as GMOs and climate change (Berkhout, Leach, & Scoones, 2005, p. 10). Some have argued additionally for the development of interactive methods involving government officials in research design and execution, thereby bringing research closer to the context of application in environmental policy-making (Turnpenny & O'Riordan, 2007, p. 103). On the other hand, rather than being object-oriented, interdisciplinarity can be practice-oriented in the sense that, where a disciplinary division of labour persists, cross-disciplinary collaboration is idealized as a value in itself, and one that outweighs any particular project (Born, 1995, chs 7, 8; Strathern, forthcoming). Commentaries on art-science, for example, sometimes portray the microsocial collaborative endeavour between artists and scientists as a crucible for creativity and as itself a focal value.

We have suggested that interdisciplinarity takes a range of forms with distinctive effects.[8] While the discourse of Mode-2 alerts us to the importance of accountability in contemporary science policy, in its desire to discern a unitary epochal shift it collapses a number of alternative modes and trajectories of interdisciplinarity. The difference that environmental social science can make to natural-scientific environmental research, or that ethnography can make to computer-science-led design in industry or HCI (human-computer interaction) research, or that art-science collaborations can make to artistic or scientific practices cannot be understood solely in terms of making good an absence of connection to society, a lack of cognizance of users or a lack of public engagement with science. Rather, for some of their proponents such fields are intended to effect qualitative transformations, experimenting with and establishing new forms of practice that exist in an agonistic or antagonistic relation to, and that may destabilize, existing disciplines and practices. Yet while these kinds of interdisciplinarity cannot be cognized in terms of an additive synthesis of 'antecedent disciplines', and despite agonism or antagonism evident in a critique of disciplinary norms, a central concern of such research may well be strenuously to rebound on those antecedent disciplines, with the aim of reconfiguring their boundaries, objects and problematics.

If the integrative-synthesis mode can augur epistemic transformations, and if the service-subordination mode, with its disciplinary division of labour, does not necessarily afford even this, then what is striking about the agonistic-antagonistic mode is that it is intended to effect more radical shifts in knowledge practices, shifts that are at once epistemic and ontological. Indeed in what follows we propose that the three interdisciplinary fields that we

studied evidence a privileged relation between the agonistic-antagonistic mode and the logic of ontology. To demonstrate this it is necessary to employ the framework outlined earlier, and specifically to do two things: first, through an account of the particular genealogies of each field, to indicate how the agonistic-antagonistic mode can only be understood diachronically in terms of a dynamic commitment to superseding prior ontological commitments with a new ontology; and, in doing so, to convey how this dynamic cannot be grasped by attributing a spurious unity. Instead, each interdisciplinary field must be analysed as precisely in play – as a heterogeneous unity or multiplicity.

Logics of interdisciplinarity

According to a number of authors and policy initiatives, interdisciplinary research can be justified in terms of a *logic of accountability* (Nowotny *et al*., 2001; Strathern, 2004). In this view, as we have noted, interdisciplinarity is guided by the idea that it helps to foster a culture of accountability, breaking down the barriers between science and society, leading to greater interaction, for instance, between scientists and various publics and stakeholders. In our research this logic appeared in several guises. It could be a matter of defending or legitimizing the sciences by providing them with a protective layer of social scientific expertise or public engagement – in this way deflecting potentially more disruptive criticisms or fulfilling legislative requirements or guidelines for public consultation. In some cases it appeared as though the minimal performance of interdisciplinarity through the employment of social scientists in a natural scientific laboratory could be held out as an indicator of accountability (Strathern, 2004). Moreover, '[a] frequent rhetorical elision in governmental and other public statements is that between dealing with materials in an interdisciplinary way and being able to communicate to anyone (stakeholders)' (Strathern, 2006, p. 202). Similar currents are at work in the British art-science field, which emerged in the 1990s in response to a series of funding schemes including the Wellcome Trust's Sciart programme and the Arts Council England/Arts and Humanities Research Council's Art-Science Fellowships. While the ACE/AHRC scheme entailed a different rationale, the Wellcome Trust's programme was predicated on the 'public understanding of science' paradigm: that art can be used to popularize or communicate science and its social, cultural and ethical dimensions, whether through aesthetic elaboration or by rendering scientific discovery comprehensible by expressive means – an aesthetizing legitimation that might obviate other forms of accountability. Here, artists' collaboration with scientists is expected to effect a wider social engagement.

But it would be wrong to contend that the social sciences or arts always function as instruments of legitimation. There is evidence that certain social movements have come to play an active role in directing or conducting scientific research (Callon, Lascoumes, & Barthe, 2001). Moreover, social

scientists are developing potentially inventive ways of engaging publics in scientific debate through practices such as deliberative mapping and participatory integrated assessment. These interventions can be justified both on the basis that they encourage publics and governments to 'buy into' the results of the research and on the grounds that they may make scientific institutions more responsive to the demands and concerns of non-scientists.

In our study of environmental research, the German Öko-Institut can be seen to represent a radical vision of accountability, through an inversion of the standard hierarchy of relations between the natural sciences and social sciences or political activism. At the time of its foundation in 1977, it was conceived as a kind of service provider delivering scientific evidence to buttress the protests led by civic action groups in south-western Germany. Its aim was to support civic protest with scientific argument and to develop a counter-science (*Gegen-Wissenschaft*). We see a similar inversion in some kinds of art-science. On the one hand, the idea of public understanding of science represents the hierarchical arrangement in which art serves to render science communicable, comprehensible or beautiful. On the other hand, in an alternative lineage of art-science, one more evident in our case studies in Australia and the USA but also significant in the UK, this instrumental function is resisted; instead, the field is contaminated by a series of troubling genealogies, notably certain conceptual art and art and technology movements, which proffer practices and objects that are incommensurable with disciplinary art or science. In this way art-science is caught up in a nexus of developments stemming from conceptualism's refusal of notions of autonomous art and its foregrounding of art's social embeddedness, including public art as social research, art that probes mediation and publicity, and art that engages the politics of science and technology. There is, therefore, a multiplicity of accountabilities evident in interdisciplinary practices, from legitimation and regulation to radically critical and militant forms.

While accountability has been central to a variety of initiatives involving social scientists and artists in the environmental, techno- and biosciences, this is not the exclusive logic governing such interdisciplinary engagements. Arguments for the involvement of social scientists, and sometimes artists, in natural science and engineering research have been guided also by a *logic of innovation*.

In our research, the logic of innovation is most pronounced in the growth of ethnographic research in the IT industry, where ethnography has been widely promoted as a solution to the problem of connecting businesses to the 'unarticulated desires' of their customers, desires that are not sufficiently identified or evoked by older and more conventional forms of market research and that it is believed can drive innovation. We might say that ethnography in the IT industry offers a set of techniques through which businesses are expected to be able to transform their knowledge of and engagement with those micro-spaces of social life, replete with social and cultural difference, to which they previously did not have access (Thrift, 2006, p. 283). To this end,

ethnographers in the IT industry may collaborate closely with different communities of practice within the firm, fine-tuning the design of products by offering analyses of how they are likely to be of value to users, and occasionally even developing prototypes in interdisciplinary teams.

But ethnography also has less immediate applications, providing, for example, broader portraits of diverse contexts of consumption that feed into thinking about long-term strategies, such as possible future openings in and demands from emerging markets (Thrift, 2005). In addition, in directing corporations to consider the ways and contexts in which technology is used, ethnography can be employed to challenge narrowly technology-driven investment strategies (Miller & O'Leary, 2007). According to a leading corporate innovation strategist,

> Success exists at the intersection ... of three domains [user value, business value, technology] and reaching the center is inherently a mixed-discipline process. It requires that the technologist or engineer be able to constructively interact with these other, non-technical disciplines [ethnography and market analysis]. That typically requires having a good understanding of why other domains matter, what vocabulary they use, and how their work relates to the engineer's work.
>
> (D'Hooge, 2005, p. 4)

In an era in which businesses have increasingly mediated relations with their customers, there is an escalating demand for ethnography to proffer what may appear to be direct and naturalistic connections to those intimate and exotic spaces, relations, practices, bodies and affects that are perceived to be missing or to have been lost – or at least to stage that connection or provide a proxy for it (Suchman, 2000). In this way, by elucidating the 'real value' of technological products for users, ethnography is expected to access some of those 'external excesses' that are vital to capitalism, the source of its energies and the condition of its success (cf. Mitchell, 2002, p. 303).

Ontologies and entanglement

From the examples of environmental social science and ethnography in the IT industry, interdisciplinary research might seem to arise primarily in response to wider social and economic demands. But what is striking across a range of fields is the stress placed by researchers on conceiving and justifying interdisciplinarity not only in terms of a logic of accountability (however it is understood) or a logic of innovation, but in terms of an *ontological logic* (cf. Lawrence & Després, 2004, p. 398). In what follows we trace the distinctive nature of the logic of ontology in each of our three interdisciplinary fields, while pointing to its entanglement with the other logics we have identified.

Ethnography in the IT industry

If the field of ethnography in the IT industry seems, at first sight, closely tied to the logic of innovation and to the commercial imperatives of the firm, it is also associated with ontological rationales. Ethnography in the IT industry has a long history, with multiple genealogies and perspectives. It developed, in particular, from ethnomethodological studies of work (Suchman, 1987; Bowker, Star, Turner, & Gasser, 1997), as well as sociological and phenomenological critiques of artificial intelligence. In addition, it draws inspiration from the Scandinavian Participatory Design movement, which addressed issues of workplace democracy (Schuler & Namioka, 1993). In the IT industry and academic HCI research, efforts to bring ethnomethodological and other ethnographic approaches together with design led in the mid-1980s to the emergence of the interdisciplinary field of Computer-Supported Cooperative Work (CSCW). Within the broader space of HCI research, ethnography appeared to offer 'a means by which the complexity of real-world settings could be apprehended, and a toolkit of techniques for studying technology "in the wild"' (Dourish, 2006, p. 2). More recently, some ethnographers in the IT industry have drawn extensively on academic research in cultural anthropology (e.g. Clifford & Marcus, 1986) and the sociology and anthropology of technology (e.g. Miller & Slater, 2000), while others have been influenced by interaction design (e.g. Gaver, Dunne, & Pacenti, 1999). The success and visibility of ethnography in the IT industry have caused the techniques to be imitated across new domains, notably in market research and other industries including banking, pharmaceuticals and media (Born, 2004, ch. 7).

The result of these complex genealogies is a heterogeneous field dispersed across a range of commercial and academic institutions, one that is in formation and the boundaries of which are etched by continuing controversies. The most prominent such controversy centres on the imbrication of the logic of ontology and that of innovation. It has two critical modalities. First, there is an ongoing debate among ethnographers in the IT industry, involving multiple perspectives, concerning the relative merits of different theoretical and methodological accounts of the social, including those derived from the traditions of ethnomethodology, science and technology studies, and social and cultural anthropology, and how they can be articulated with industry and HCI research. Second, there is a spectrum of positions on the question of the relation between ethnography and design (Salvador, Bell, & Anderson, 1999). For some, ethnography in the IT industry should be thoroughly integrated into a practice of user-centred design; for others, the ontological and theoretical claims of ethnography should be quite clearly distinguished from any particular design implications (Dourish, 2006). In individual research groups, the performance of distance from the immediate demands of the corporation for improved product or process takes diverse forms. It can involve orienting research towards the production of academic journal articles and conference papers rather than industrial designs; it can take the form of a

critique of the politics of industrial ethnographic practice (Anderson & Nafus, 2006); it can entail the development of designs that are not necessarily intended to be the basis for products; and it can take the form of research with no discernible relation to consumer demand or design: 'Our role is not to design a new and better application for X or a new and better gadget.'[9]

There is much to be said about why some ethnographers distance their work from expectations that it should impact on design. It may be difficult for them to demonstrate any direct impact and, even if their work does have implications for design, to discuss these in public because of commercial confidentiality. At the same time, ethnographers are more likely to achieve such distance in those corporations able to pursue a long-term research strategy, as well as those that collaborate with universities or that fund university-linked research outfits. In this situation researchers act as a porous interface with their counterparts in academia, picking up currents across the Chinese walls (Amin & Cohendet, 2004); the corporation gains legitimacy by being seen to support research with no immediate economic utility:

> What the research group does is provide visibility for the company: we'd go to the conferences, give keynotes and say, 'this is X! [the corporation]'. The managers always said it was really important for us to publish, give talks and be visible in the research community; sometimes we'd be interviewed by the press. They get a lot of PR out of having interesting researchers on board.[10]

Yet it would be a mistake to view demonstrations of autonomy by corporate researchers as mere performance or PR, even if they may sometimes be considered such by corporate managers. On the one hand, they demonstrate the possible contribution of ethnography in industry to academic debates. Indeed, some industry researchers argue that the corporate context makes it possible to carry out forms of ethnography that are difficult to achieve in academia, including sustained and intensive collaborations with designers and computer scientists (cf. Stefik & Stefik, 2004). On the other hand, they express a sense that the justification of the role of ethnographer is in large part ontological: that s/he must effect an ontological transformation. The rationale for carrying out ethnography, then, is not just that it may impact on design, but that it has the potential to transform the technological object from being merely an object or product into something which, depending on the approach, is locally situated, socially contextualized, emotionally attached or encultured (e.g. Suchman, 1987; Suchman *et al.*, 2002; Bowker *et al.*, 1997; Nardi & O'Day, 1999; Dourish, 2001; Harper, 2003). In this respect ethnography in the IT industry draws on and, through collaboration with designers and computer scientists, contributes to much longer traditions of philosophical and social enquiry concerning the nature of technology. Of course, the ontological contribution of the ethnographer may nonetheless have implications for design or contribute to sophisticated market research.

At the same time, ethnography may be employed in efforts to achieve a transformation of what we might call the ontological imagination of the firm,

towards a conception of the intentional-industrial object as a socio-cultural-technical assemblage (Bell, Brooke, & Churchill, 2003; Dourish, 2006). Through such efforts the ontological labours of corporate ethnography are both translated and expanded into an organizational and industrial practice, to potentially inventive effect (Tarde, 2001, 2007). The problem faced by corporate ethnographers in seeking to produce such a transformation at the level of corporate strategy and imagination is at base a rhetorical one. The challenge may not be how to provide a detailed and nuanced description of an Indian middle-class home, an American public library or a Russian street, but how to demonstrate the ontological truth that technical objects have to be situated in particular microsocial and encultured spaces. Corporate ethnography can be marked by an emphasis on charisma, rhetoric and display, but rhetoric is necessary for truth to survive in harsh conditions (Cassin, 2005).

Environmental and climate change research

The logic of ontology is at work in a different guise in the field of environmental and climate change research. Here, as we have noted, the development of interdisciplinary institutions responds to the logic of accountability and has a problem-solving orientation: because environmental issues are objects of immense public and political concern, they raise issues of accountability; and, in as much as they pose multi-dimensional problems, they evoke interdisciplinary approaches.

Yet, along with the stress on accountability and problem-solving, it is possible to discern two distinct sets of ontological and epistemological arguments developing in the field of environmental and climate change research. The first set of arguments was associated with the emergence of the field of climate science in the 1970s. Climatologists in the 1960s still represented climate change primarily using long-term statistical databases. However, by the late 1970s computer-based models had become increasingly prevalent. Since then, in the context of the developing interdisciplines of climate science and earth systems science, the global environment has come to be understood and modelled as a set of systems of varying scales and levels of resolution and complexity (Edwards, 2001, pp. 32–3). Within this frame, the contribution of the social sciences is expected to be the provision of one element of an integrated analysis of the global environment. Here, the global environment is conceived not just as a system or set of systems, but as an object of global government (Schellnhuber, 1999, p. 20).[11]

More recently, however, a different set of ontological arguments have been made in environmental research, drawing on a range of intellectual traditions including science and technology studies, social anthropology, cultural geography, natural hazards research, political ecology and poststructuralist theory. Although these arguments have a long history, they did not become well-established in environmental research until the late 1990s (Liverman,

1999). There are three strands to these arguments, which are sometimes elided. One proposes that the dominant understanding of natural science models of the environment fails to address the ways in which such models are shaped by political assumptions and cultural values: 'it is not that the scientific models and ensuing knowledge are empty of culture and politics, but that they are impregnated with them without even recognising it, let alone the implications' (Shackley & Wynne, 1985, p. 124). Moreover, in this account, the uncertainties of scientific knowledge claims, including climate change models, are seldom acknowledged in public debate (Jasanoff & Wynne, 1998).

A second argument starts from an awareness of the limitations of scientific expertise and a recognition of the importance of local and indigenous knowledges of the environment. In this view, lay and non-expert accounts of environmental problems and issues should not be understood merely as perceptions, but recognized as expressions of a kind of scientific citizenship (Barry, 2001; Hulme & Turnpenny, 2004; Berkhout *et al.*, 2005, p. 12; Leach, Scoones & Wynne, 2005). In this context, while devices such as public consultations and inquiries may often be anti-inventive, legitimizing existing forms of political assembly, other ways of engaging non-experts in environmental debate and research may be more generative (Callon *et al.*, 2001; Stirling, 2005; Davies, 2006). Such inventive forms of inter- and extra-disciplinary practice involving non-experts are frequently justified in terms of their contribution to greater accountability. However, both experts and non-experts must also perform the difficult task of demonstrating the autonomy of these new interdisciplinary practices from this logic. That is to say, the involvement of non-experts in research and public debate may have critical implications for policy and practice precisely in so far as it cannot be dismissed either as an expression of a pre-determined politics or as a response to demands for accountability (Barry, 2001).

These two arguments point in turn to a third, more encompassing ontological rationale. In this account, the development of environmental policy and politics has implications for the relations between the natural and social sciences not because the environment is a complex system of natural and social elements, but because environmental issues raise fundamental questions concerning the very distinction between the natural and the social (Whitehead, 1985; Latour, 2004; Whatmore, 2002; Jasanoff, 2004). Yet, while this argument has been made intellectually in the social sciences, its implications for the conduct of interdisciplinary environmental research and for policy remain contested and in development (Berkhout *et al.*, 2005).

In relation to these ontological arguments, interdisciplinary environmental research appears more fragmented as a field than ethnography in the IT industry. Whereas ethnography provides a core method around which ontological issues can be raised and demonstrated in the IT industry and which, however interpreted, serves to give some sense of heterodox unity to the interdiscipline, there is no such core method in interdisciplinary environmental research. Instead there is a multitude of ways of re-conceiving the environment

associated with different social science disciplines, approaches and techniques, including computer modelling, systems analysis, scenario analysis, environmental economics, public participation methods and ethnography.

Art-science

Of the three fields that we studied, perhaps the purest expression of the logic of ontology occurs in the burgeoning field of art-science. While art-science is a practical, intentional category for artists, institutions and funding bodies, it forms part of a larger, heterogeneous space of overlapping interdisciplines thrown up at the intersection of the arts, sciences and technologies, including such practices as new media art and digital art, interactive art and immersive art, bio-art and wet art, just as these domains abut adjacent interdisciplines from robotics, informatics, artificial and embodied intelligence to tissue engineering and systems biology (Wilson, 2002). There is a ferment of activity but as yet little codification; practice runs ahead of theory. We might consider art-science, then, as an emergent field. At its core are long-standing concerns to shift the ontological grounds of what art is or can be, evident in recent decades in diverse practices that probe the relations between both art and technology and art and the social. Although the perspective varies according to individual and institutional location, art-science and its cognates can be understood to have their genesis in the mutual interferences set up between three broad and related genealogies: 1) conceptual and post-conceptual art, including performance, installation, public and activist art; 2) art and technology movements; and 3) certain developments and debates around the computational and bio sciences and technologies.[12]

Conceptual art generated a series of directions that are still influential in a range of contemporary art practices, including art-science. Its basic premise is a commitment to an entirely distinctive ontology of art, indeed to pluralizing art's ontologies. Originating in responses in the 1960s to the impasses of formalist modernism, conceptual art entails a questioning of art as object, as site and as social relation, each of which has been targeted for transformation by distinctive conceptual lineages. Conceptualism, then, can be sketched through a series of negations: negation of material objectivity and the primacy of the visual – in favour of the temporality of multimedia performances and events; negation of art's commodity form – in favour of installations, site-specific and performance works; and negation of the philosophy of art's autonomy, and this in several ways – in favour of works that address the politics of everyday life through interventions in media and publicity, works allied to wider political and ideological conflicts, works that probe the politics of art as an institution, and works that foreground art's social relations, re-conceiving art as various kinds of social practice (Osborne, 2002; Corris, 2004; Buchmann, 2005). Running through conceptual art is a constitutive tension between orientations that are primarily to do with medium and materials, and

those that are primarily concerned with social and political experiment (Newman, 2002) – a tension recapitulated in art-science. Indeed, in the politicized lineages of art-science, science and technology studies, critical and feminist theories may be brought into the mix in an attempt to build a systematic reflexivity into the new practices. Art-science engages science, then, for its conceptual and material armouries, in terms of common interests in experimentation and innovation, and via critique. Together, the genealogies of art-science etch out a decidedly artistic space, but one that intersects with technological and scientific experimentation and controversy, in which art is retooled, as an informant put it, as 'interdisciplinary production'.

Prominent in Britain, as mentioned earlier, are currents connecting art-science to accountability. Whether in the Wellcome Trust's 'public understanding of science' funding programme or its 'public engagement' successor, art-science 'has been sold around a very pragmatic and instrumentalist notion' of reaching new audiences for science.[13] Despite efforts to combat this limiting image, there is a perception that the combination of this instrumental conception with the limited time allowed by project-based funding schemes preys on artists' precarious financial standing and can result in poor work. This points to a key line of fracture within the field, in which the output from such project-based schemes – where collaboration between artist and scientist is usually short-lived and the division of labour remains intact; that is, where art-science labours in a service-subordination mode under the logic of accountability – is often characterized as 'decorative', 'celebratory' or superficial. In contrast, originality and invention in art-science are commonly associated with those practices in which the engagement or confrontation between art and science is deeper and sustained, and in which artists are trained to make full and knowledgeable use of the 'special facilities of the scientific lab', engineering workshop or computer workstation.[14]

As visible as the public understanding of science rationale for art-science has been a justification in terms of the logic of innovation. In one influential account, the focus is on a particular social form, the 'studio-lab', as a site of hybrid experimental activity 'where new media technologies are ... developed in co-evolution with their creative application' (Century, 1999, p. 2; cf. Born, 1995). The studio-lab is portrayed as a valuable incubus for innovation; science is seen to proffer new subject matters, concepts, imagery, technologies and materials for artistic experimentation. More generally, artists' engagements with scientific and technological research are considered to offer a range of potential stimuli or aids to innovation. Collaborative projects between artists and scientists may provoke and enrich scientific research, triggering unforeseen directions; they may assemble an unconventional mix of disciplinary skills and talents; the artist can offer the content required for the testing of new tools; artists' responses to new research or materials can allow scientists to observe human responses and behaviour; artists may act as particularly acute or creative 'lead users', generating further development; or the artistic exhibition of research outcomes may act as a test-bed for their launch in the

real world (Naimark, 2003). In Britain, the ACE/AHRC Art-Science Fellowship programme makes clear the grounding of some art-science in the entanglement of the logics of innovation and ontology. The fellowship scheme responded explicitly to the call from government bodies such as the 2001 Council on Science and Technology for the arts and humanities to contribute to the knowledge economy (Ferran, 2006, p. 443). At the same time, collaborations between artists and scientists funded by the programme could be guided by an ontological logic, in which the collaborative endeavour is itself envisaged as both methodology and as the 'work': 'we consider our overall objective as a new kind of social "material", aiming to create new cultures of technological collaboration and artistic production' (Blackwell & Biggs, 2006, p. 471).

In our institutional case studies, these inventive modalities of art-science, combining the logics of ontology and innovation, were particularly apparent in the USA and Australia, where university-based, salaried artists were able to achieve intensive collaborations with scientist colleagues and prolonged encounters with scientific environments, thereby incorporating scientific problematics into their work to occasionally extraordinary synergistic effect (Born & Weszkalnys, 2007). Moreover such conditions provide the basis for transcending the disciplinary division of labour through a commitment to developing interdisciplinarity in one person. At UC Irvine, for example, this takes the form of a master's programme in arts, computation and engineering (ACE) devoted to producing a new kind of subject trained in elements of all three fields, as well as a range of critical theories, and their articulation. Transcending mere 'decorative' art-science, the ACE programme foresees a generation possessed of a growing intimacy with these disciplines, equipped to develop rich 'interlanguages' between them (Galison, 1997), and endowed with a reflexive sense of the epistemological and ontological implications of this project – subjects, that is, empowered to negotiate a transition to a new and potentially inventive ontological space.

Conclusions

It is a commonplace to observe that both business and government seek to foster and draw energy from research and development. The contemporary emphasis on interdisciplinarity can certainly be understood in these terms. Interdisciplinary research is expected to bring science and technology closer to the needs and concerns of citizens and consumers, reducing the risks of public resistance, uninformed criticism or indifference and stoking the engines of innovation. In this light, the contemporary enthusiasm for interdisciplinarity can be seen as driven by a political and economic strategy of 'empowering pacification' (Toscano, 2007).

Yet, while it is true that interdisciplinarity has been closely associated with the logics of innovation and accountability, it is not reducible to them. We have

emphasized the heterogeneity of interdisciplinary fields, drawing attention to the ways in which, to a variable extent in each of the fields that we observed, they may also be governed by an ontological logic. In arguing for the significance of the logic of ontology, it may appear that we are replacing political or economic explanations of the contemporary preoccupation with interdisciplinarity with an internalist one. But in practice, as we have argued, the logics are entangled. Recognition of the importance of the ontological claims of environmental social science has in part been prompted by the need to respond to and intervene in a series of environmental-political issues, including nuclear power, BSE, GM crops and climate change. Likewise, the value of ethnographic practice in the IT industry is thought to be both that it enables designers and executives to have a richer grasp of the social life of technical objects and, in the context of intensifying global competition, that this might contribute to better design or to the long-term profitability of the firm. The ontological logic of ethnography in the IT industry is both entangled with the logic of innovation and irreducible to it. In art-science, in contrast, while the logics of ontology and innovation may be intimately bound, while the logic of accountability provides a basis for patronage and while the logic of ontology itself responds to the broader changing conditions of cultural production, given that art's 'normative spirit is one of autonomization' (Osborne, 1998, p. 110), the logic of ontology must be considered primary.

While the three logics are interdependent, then, they are not reducible to each other. Part of the value of ethnography to the IT industry is thought to lie in the fact that its claims are not simply driven by commercial imperatives or a narrow consumer orientation; by resisting instrumentality, ethnography provides access to aspects of social reality that the corporation would not otherwise have. Similarly, the value of interdisciplinary environmental research may lie in the extent to which its outcomes go beyond the demands for accountable science. And if the logics of innovation and accountability appear to play a prominent part in art-science, according to the values of the emergent field they should be counted as secondary to the ontological logic unleashed by the fertile genealogies of conceptual art and their heterogeneous issue. It is by resisting simple accountability, and by elaborating conceptually on simple innovation with reference to the post-conceptual legacies of recent decades, that art-science is thought to come into its own.

In highlighting the logic of ontology, we have tried to bring out certain tendencies inherent in particular fields that might go unrecognized. It would be wrong, for example, to imagine that corporate ethnography is in any way opposed to business. But, as we have been at pains to point out, as a knowledge practice it has its own positivity. As such it may function as something of an irritant to business, identifying certain issues – such as social and cultural differences or disjunctures between norms and practices – which create frictions that prove difficult for business fully to metabolize, at least in the short term. However, we do not wish to overplay the significance of the logic of ontology, the framing of which may be more or less restricted. In industry,

for instance, ethnographers are largely confined to researching the microsocial spaces of consumption and work, and have not been much concerned with studying corporate investment decisions, market analysis or accounting practices (cf. Barry & Slater, 2005; Born, 2004, 2007); while in climate change research, discourses of system and integration continue to provide the dominant frame within which the question of interdisciplinarity is posed.

Finally, we want to raise the prospect of a re-evaluation of interdisciplinarity. We are not enthusiasts for interdisciplinarity *per se*, and do not mean to suggest that there is a necessary or privileged affinity between interdisciplinary research and invention. As we have indicated, any analysis of the inventiveness of particular kinds of interdisciplinarity must attend to the specificity of interdisciplinary fields, their genealogies and multiplicity.[15] At the same time, it may be tempting to think that there is a straightforward equation between the disruption of disciplinary boundaries and the erosion of autonomy. Recent accounts of interdisciplinarity certainly encourage that belief. In these circumstances it is perhaps not surprising that, in reaction against the drive in science policy to expand interdisciplinarity, some authorities seek to defend disciplinary purity as a way of protecting academic autonomy. But, as we stated at the outset, disciplines are not infallibly autonomous or inventive; they have unproductive phases and can exhibit inertial and anti-inventive dynamics. In this paper we refer to autonomy not in order to criticize this ideal, but to indicate the existence of forms of *inter*disciplinary autonomy and rigorous interdisciplinarity that lead to the production of new objects and practices of knowledge, practices that are irreducible both to previous disciplinary knowledge formations and to accountability and innovation.[16]

Notes

1 There are few empirical studies of contemporary interdisciplinary research. Recent examples include Bruce *et al.* (2004), Mansilla (2006, n.d.), Tait and Lyall (2001), Rhoten (2004) and Tompkins (2005).

2 Our research was funded by the ESRC under the Science in Society Programme: 'Interdisciplinarity and Society: A Critical Comparative Study', RES-151-25-0042-A, investigators Andrew Barry, Georgina Born and Marilyn Strathern.

3 The ten case studies were: 1) environmental and climate change research: the Tyndall Centre, University of East Anglia; the Earth Institute, Columbia University; the Öko-Institut, Darmstadt and Freiburg; 2) ethnography in the IT industry: three IT corporations; the Institute for Software Research at the University of California, Irvine; and 3) art-science: the Arts, Computation and Engineering (ACE) Master's programme, UC Irvine, and Digital Arts Research network (DARnet) of the University of California; the Symbiotica lab, University of Western Australia; and project-based funding programmes supported by the Wellcome Trust and Arts Council England. In this paper we do not address differences between interdisciplinary research in the US, Germany and the UK. A third element of the overall ESRC project, carried out by Marilyn Strathern and Elena Khlinovskaya Rockhill, was an ethnographic study of another interdisciplinary field: collaboration between research on ethical, legal and

social implications and genetics research. Although this study complements our own work, we do not address it directly here.

4 By contrast, one could note the importance of interdisciplinary research in the development of military science and technology in the 1940s and 1950s (Pickering, 1995; Edgerton, 2006).

5 Our research partakes in the broader 'ontological turn' within the social sciences (see, for example, Mol 2002, Barry 2005 and Henare, Holbraad, & Wastell, 2007); and in other projects we have ourselves engaged in interdisciplinary research with natural scientists, engineers and artists. In writing of the logic of ontology, then, this paper is in part a reflection on the rationale for our own work; and, in studying those engaged in fostering ontological transformations in their research and practice, we acknowledge the inevitably recursive nature both of our project and of our analyses. In spite of these qualifications, we suggest that the detour through empirical observation and enquiry represented by this study lends acuity, complexity and objectivity to our account of these phenomena.

6 See, *inter alia*, Petts *et al*. (in press), Lawrence and Després (2004, p. 400) and the discussion on <www.interdisciplines.org>.

7 This irreducibility has important implications for the evaluation of this kind of interdisciplinarity which we outline in Born and Barry (2007).

8 It may be worth clarifying briefly the relations between the three modes of interdisciplinarity outlined in this section and the descriptive definitions given earlier. In short, there is no one-to-one mapping. While the integrative-synthesis mode can characterize interdisciplinarity (but not multidisciplinarity or transdisciplinarity), the hierarchical division of labour of the subordination-service mode can characterize both interdisciplinary and multidisciplinary research. The agonistic-antagonistic mode, finally, can characterize both interdisciplinary and transdisciplinary research (but not multidisciplinary).

9 Interview with a former corporate ethnographer, now in a university setting, February 2006.

10 Interview with a long-standing corporate ethnographer, now in an academic setting, February 2006.

11 See Jasanoff and Wynne (1998), Demeritt (2001) and Miller (2004) on the co-construction of the global environment as an object of knowledge and government. On the lack of a relation between climate change science and policy during the 1950s and 1960s, see Hart and Victor (1993).

12 The genealogies are commonly traced from origins in Muybridge and Duchamp, founding father of conceptualism, via mid-century figures and groups such as Cage, Tinguely, Kluver and Experiments in Art and Technology, Art and Language, Nam June Paik, Jack Burnham, Jim Pomeroy, Hans Haacke and Artist Placement Group, to contemporary figures including Laurie Anderson, Perry Hoberman, Natalie Jeremijenko, Geert Lovink, Eduardo Kac and groups such as Adbusters, RTMark, Critical Art Ensemble, Survival Research Labs, Red Group at Xerox PARC and Symbiotica.

13 Interview with a British art-science administrator, May 2005.

14 Interview with a leading exponent of art-science, August 2006.

15 For a discussion of the methodological underpinnings of this approach, see Born (forthcoming).

16 Our thanks to Gail Davies, Paul Dourish, Sheila Jasanoff, Lucy Kimbell, Bill Maurer, Susan Owens, Lucy Suchman, Brian Wynne, several of our informants and the anonymous referees of *Economy and Society* for extensive and helpful comments on an earlier draft of this paper. We extend our gratitude also to all those individuals that we interviewed and observed during the course of our research, to the participants in the 'Interdisciplinarity and Society' conference in Oxford, February 2007, at which we presented our initial findings, and above all to Marilyn Strathern and Elena Khlinovskaya Rockhill for ongoing conversations and productive collaboration.

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