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Competition Processes and the Management of Innovation

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ABSTRACT *This paper presents two different forms of research practices: Mode 1 and Mode 2. These forms of knowledge production are adumbrated not so much to demonstrate their radical differences, though there are some, but as a way of calling attention to the fact that, in both modes, static and dynamic competition are at work. It will come as no surprise to academics to be told that their research is carried out in a competitive context. Competition for ideas and for intellectual leadership in a particular field or sub-field is the bread and butter of academic life. In industry, too, the observation that research takes place in a competitive environment would be uncontentious were it not for the fact that researchers in business management seem reluctant to take on board the uncertainties that competition generates and to put their intellectual energies into developing specific strategies that are appropriate to two diverse forms of competition. The argument moves on to spell out the differences that specify static and dynamic competition, as they occur in the innovation process. This raises the crucial question of the importance of boundary work in generating innovation in both academic and industrial contexts. The nature of boundary work is then related to different types of competition and then to the appropriate organisational imperatives of each. The paper concludes by asking for how much longer can research into business management carry on ignoring the fact that fundamentally different approaches to management are required in these two radically different environments.*

Keywords: knowledge production, competition, design configurations, transaction spaces.

Introduction

This paper examines the implications of the emergence of new modes of knowledge production for the management of innovation. It begins with a brief description of the differences between research carried out under the imperatives of the disciplinary structure of science and scholarship, on the one hand, and research carried out in the context of application, on the other hand. The former has been pursued primarily in the context of universities where the disciplines have until recently been the dominant form of organisation but, for reasons that have been described elsewhere,[1] the disciplines are themselves becoming more open,

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permeable and heterogeneous and this, in turn, has allowed the emergence, in universities, of research that is carried out in the context of application as well as more differentiated forms of industrial–academic collaboration. Some have contested both the emergence and the importance of new modes of knowledge production. Indeed, it has generated a lively debate, one aspect of which has been to conclude that research carried out in the context of application is the form properly appropriate to industry and that its adoption by universities constitutes a betrayal of the fundamental values of autonomy and independent inquiry which have always characterised them. The argument of this paper leaves that debate to run its course and focuses, instead, on an aspect that they have in common: research, whether carried out in universities or industry is driven by competition.

In the first section of this paper, the basic differences in research practices between Mode 1 and Mode 2 forms of knowledge production are adumbrated not so much to demonstrate their radical differences, though there are some, but as a way of calling attention to the fact that, in both modes, the same two types of competition—static and dynamic—are at work. It will come as no surprise to academics to be told that their research is carried out in a competitive context. Competition for ideas and for intellectual leadership in a particular field or sub-field is the bread and butter of academic life. In industry, too, the observation that research takes place in a competitive environment would be uncontentious were it not for the fact that researchers in business management seem reluctant to take on board the uncertainties that competition generates and to put their intellectual energies into developing specific strategies that are appropriate to two diverse forms of competition. In the next section the argument moves on to spell out the differences that specify static and dynamic competition, as they occur in the innovation process. In this context, static competition is most obvious in the search for efficiency gains. Dynamic competition, by contrast, is a driver of creativity as firms search for new design configurations which will increase the probability that they will be able to survive a major competitive challenge. As with academics, industrial managers, too, pursue strategies that aim at both efficiency and creativity.

Then, the following section explores the nature of dynamic competition and particularly the role of collaboration in the search for novel design configurations. This raises the crucial question of the importance of boundary work in generating innovation in both academic and industrial contexts. In the next section the argument turns to examine the implication that static and dynamic competition respectively generate their own, specific forms within organisations. The former are often described as areas of stability, the latter as areas of instability. Each requires a different framework if it is to be managed effectively. As is well known, strategic management in areas of stability is dominated by input–outcome models but what precisely the organisational tools are for managing areas of instability still need to be worked out.

The implications of the differences in managerial approach between areas of stability and instability are of crucial importance not only in academic science and industrial research but also, *a fortiori*, for those who would carry out research into the management of the innovation process. Accordingly, the paper concludes by asking for how much longer can research into business management carry on ignoring the fact that fundamentally different approaches to management are required in these two radically different environments.

The Role of Competition in University Research

It will be helpful to begin, first by describing briefly the range and power of the disciplinary structure as it operates in universities and, second, by laying out what amounts to a new set of research practices that differ in almost every respect with the way research currently works within disciplines in universities. As will become clear, the principal differences between the two sets of research practices can be described in terms of what has been labelled Mode 1 and Mode 2 forms of knowledge production.[2] In a subsequent section of this paper, an explanation is offered about how Mode 2 emerges and how it relates to competition.

The Organisation of Research in Universities

The research structures that have gradually been put in place in universities are supported by a set of research practices which ensures that results are sound. These research practices set the rules of the game; that is the terms of what shall count as a contribution to knowledge, who shall be allowed to participate in its production, and how accreditation shall be organised. Together, these practices underpin what we know as the disciplinary structure of science and scholarship and this structure, in turn, has come to play a central role in management and organisation of universities today. Of particular importance is the fact that the disciplinary structure is specialist. Whether in sciences, the social sciences, or the humanities, specialism has been seen as a secure way to advance knowledge and its organisational imperatives have everywhere accompanied its adoption.

The disciplinary structure also organises teaching in universities by providing a framework for the undergraduate curriculum. The disciplinary structure is the essential link which connects teaching and research and which underpins the argument that in universities they properly belong together. Of course, research not only adds to the stock of specialist knowledge but transforms it as well. The research enterprise is a dynamic one. Its research practices articulate the disciplinary structure and, over time, modify what are regarded as the essential ideas, techniques and methods that students need to be taught.

The disciplinary structure, then, has two aspects. In its cognitive aspect, it provides guidelines for researchers about what the important problems are, how they should be tackled, who should tackle them, and what should be regarded as a contribution to the solution. In its social aspect, it prescribes the rules for training and accrediting new researchers, procedures for selecting new university faculty, and criteria for their advancement within academic life. *In brief, the disciplinary structure defines what shall count as 'good science' and identifies who shall be regarded as 'good scientists'*. The disciplinary structure and all that that entails is what is meant by Mode 1 knowledge production.

Because the disciplinary structure has been institutionalised in them, universities have tended to become the primary legitimators of this form of excellence. But there is a growing amount of evidence to indicate that a new mode of knowledge production may be emerging. In keeping with academic tradition, let us distinguish it from Mode 1, and creatively label it Mode 2. It is the burden of the argument in this paper that in addition to describing different sets of research practices, Mode 1 and Mode 2 forms of research also exhibit two different types of competitive behaviour and problems of managing these are of equal importance to both universities and industry.

Mode 2 Knowledge Production

Mode 2 can be summarised in terms of five characteristics.[3]

(i) Mode 2 knowledge is generated within a *context of application*. This is different from the process of application by which 'pure' science, generated in theoretical/experimental environments, is 'applied', technology is 'transferred', and knowledge is subsequently 'managed'. The context of application, in contrast, describes the total environment in which scientific problems arise, methodologies are developed, outcomes are disseminated and uses are defined.

(ii) Mode 2 is *trans-disciplinary*, by which is meant the mobilisation of a range of theoretical perspectives and practical methodologies to solve problems. But, unlike inter- or multi-disciplinarity, it is not necessarily derived from pre-existing disciplines nor does it always contribute to the formation of new disciplines. The creative act lies just as much in the capacity to mobilise and manage these perspectives and methodologies, their 'external' orchestration so-to-speak, as in the development of new theories or conceptualisations or the refinement of research methods, the 'internal' dynamics of scientific creativity. In other words Mode 2 knowledge production, in this trans-disciplinary form, is embodied in the expertise of individual researchers and research (and project) teams as much as, or possibly more than, it is encoded in conventional research products such as journal articles or even patents.

(iii) In Mode 2 there is much greater *diversity of the sites* at which knowledge is produced and, an associated phenomenon, the growing *heterogeneity* in the types of knowledge production. The first phenomenon, it can be argued, is not especially new. Research communities have always been 'virtual' communities that cross national (and cultural) boundaries. But their dynamics have been transformed. Once interaction within these communities was limited by the constraints both physical (the ability to meet) and technical (letters and telephones); now as a result of advances in information and communication technologies interaction is unconstrained—and instantaneous. The orderly hierarchies imposed by these 'old' technologies of interaction may have been eroded by this communicative free-for-all. This shift has been intensified by the second phenomenon, the fact that these research communities now have open frontiers which has allowed many new kinds of 'knowledge' organisation—such as think-tanks, management consultants, activist groups—to join the research game.

(iv) Mode 2 knowledge is highly *reflexive*. The research process can no longer be characterised as an 'objective' investigation of the natural (or social) world, or as a cool and reductionist interrogation of arbitrarily defined 'others'. Instead it has become a dialogic process, an intense (and perhaps endless) 'conversation' between research actors and research subjects—to such an extent that the basic vocabulary of research (who, whom, what, how) is in danger of losing its significance. As a result traditional notions of accountability, such as a form of external review of mature research concepts and projects, have had to be radically revised. The consequences (predictable and unintended) of new knowledge could not be regarded as being 'outside' the research process, because problem-solving environments influence topic-choice and research-design as well as end-uses.

(v) In Mode 2, *novel forms of quality control* are emerging—for a number of reasons. First, in Mode 2 knowledge scientific 'peers' can no longer be reliably identified, because there is no longer a stable taxonomy of codified disciplines from which 'peers' can be drawn. Secondly, reductionist forms of quality control can not easily be applied to much more broadly framed research questions; the research 'game' is being joined by more and more players—not simply a wider and more eclectic range of 'producers' but also orchestrators, brokers, disseminators, users. Thirdly, and most disturbingly, clear and unchallengeable criteria to determine quality may no longer be available. Instead we must learn to live with multiple definitions of quality, which seriously complicates (even compromises) the processes of discrimination, prioritisation and selectivity on which policy-makers and funding agencies increasingly rely.

Socially Distributed Knowledge Production

The first thing to note about the emergence of Mode 2 is that knowledge production is becoming more complex than it used to be. The key change is that it is becoming less and less a self-contained activity. As practised currently, it is neither the science of the 'universities' nor the 'technology' of industry. It is no longer the preserve of a special type of institution, from which knowledge is expected to spill over, or spin-off, to the benefit of other sectors. Knowledge production, not only in its theories and models but also in its methods and techniques, has spread from the academy to many different types of institutions. It is in this sense that knowledge production has become a socially distributed process. At its base lies the expansion of the numbers of sites which form the sources for a continual combination and recombination of knowledge resources. Metaphorically speaking, what we are seeing is the 'multiplication of the nerve endings of knowledge' and these extend far beyond the boundaries of universities and disciplines housed in them.

Such is the nature of socially distributed knowledge production. As a system, it comprises a reservoir of skills and expertise which is available to enter into a variety of problem contexts and which is now attaining global proportions. In the maintenance of this reservoir, the universities play an important part by providing a supply of trained researchers, as a consequence of which they are now only one player amongst many in determining the research agenda. The socially distributed knowledge production system has five principal characteristics.

(i) There are an increasing number of places where recognisably competent research is being carried out. This can be easily demonstrated by consulting the addresses of the authors of scientific publications, though change here is taking place so rapidly that the full extent of the social distribution of knowledge production is probably no longer fully captured by the printed word.
(ii) These sites communicate with one another and, thereby, broaden the base of effective interaction. Thus, contributions to the stock of knowledge are derived from an increasing number of tributarial flows from various types of institutions that both contribute to, and draw from, the stock of knowledge.
(iii) The dynamics of socially distributed knowledge production lie in the flows of knowledge and in the shifting patterns of *connectivity* amongst these flows. The

connections may appear to be random but they move with the problem context rather than according either to disciplinary structures or the dictates of national science policy.

(iv) The number of inter-connections is accelerating, so far apparently unchannelled by existing institutional structures, perhaps for the reason that these connections are intended to be functional and to survive only as long as they are useful. The ebb and flow of connections follow the paths of problem interest, and the paths of problem interest are no longer determined by the disciplinary structure of science.

(v) Knowledge production thus exhibits heterogeneous, rather than homogeneous, growth. New sites of knowledge production are continually emerging which, in their turn, provide intellectual points of departure for further combinations or configurations of researchers. In this sense, the socially distributed knowledge production system exhibits some of the properties that are often associated with self-organising systems in which the communication density is increasing rapidly.

In summary, the distributed character of knowledge production constitutes a fundamental change both in terms of the *numbers* of possible sites of expertise and in their degree of *connectivity*. As will become evident, research which draws upon the resources of a socially distributed knowledge system uses different criteria for determining research excellence than those required in discipline-based peer review. To the extent that university researchers operate within the distributed knowledge system, they may import these different types of excellence into the university and hence begin to modify what it is to 'do' good science and scholarship in academic life.

As described, the socially distributed knowledge production system refers simply to the multiplication of the number of sites where recognisably competent research is being carried out. It is perhaps worth noting here that when, in later sections, the importance of boundary work in the innovation process is discussed, collaboration in the process of knowledge production is facilitated by the emergence of a socially distributed knowledge production system. In fact, this system, because it is multiplying the numbers of possible inter-connections between researchers, provides a sub-stratum of knowledge and expertise upon which the creative possibilities of work across boundaries draws.

The distinction between Mode 1 and Mode 2 has been described in terms of differences in research practices, but there is another difference which needs to be considered and that concerns the role of competition in academic research. No one will deny that competition, whether it be for ideas, techniques, or methods, lies close to the heart of the search for understanding that motivates university researchers. The academic market place, too, produces its winners and losers as a consequence of which certain ideas, techniques and methods are exploited to the full while others are left, for the time being, to languish. Academics who succeed in establishing their leadership in any field also gain rewards in terms of peer recognition and the benefits that accompany it; for example, access to prestigious appointments and, perhaps less importantly, monetary rewards.

None of this should be surprising, for the Austrian School of Economics observed many years ago that competition always launches a discovery process and that this process operates simultaneously at two levels which can be distinguished in terms of static and dynamic competition. In terms of academic research,

competition at the first level promotes discovery within an established framework while at a second level it promotes the search for new frameworks. Of course, at any given time, the division of labour within a discipline exhibits both types of competition. It is not a question of one type having precedence over the other. In the context of what has been described above, one might aver that, in addition to the differences in research practices, Mode 1 is characterised primarily by static competition while Mode 2 is characterised by dynamic competition. Both types of competition are necessary for scientific progress and analysts of science from Thomas Kuhn (paradigms) to Imre Lakatos (research programmes) have noted the different roles that each plays in the overall advance of science. While one would not want to push this distinction too far, it is worth noting for what follows that static and dynamic competition have different strategic and managerial implications.

Competition and the Innovation Process

To the extent that innovation is underpinned by the search for novel knowledge solutions, firms, too, must cope with the opportunities and challenges of static and dynamic competition. In addition, that a particular technological innovation might undermine, or render obsolete, the basis on which a firm stands, together with the recognition that this threat might arise from an increasing number of places located anywhere in the world, has the immediate effect of increasing competitive behaviour amongst firms. Further, since competition always launches a discovery process, it follows that an increase in competitive behaviour will manifest itself in the intensification of the search for 'knowledge solutions' that might underpin future technological or organisational innovations. Of course, one well-established way of searching for knowledge solutions is for firms to engage in R&D activities. It is perhaps because R&D is widely understood to be a source of new knowledge that it is frequently argued that in the process of innovation, knowledge has become the scarce resource. But more than scarcity is involved. Knowledge solutions by their very nature can never be completely closed, neither can they be effectively contained by legislative arrangements, or fully protected by patents for very long. Rather, it is far more likely, given the propensity of information to diffuse, that any particular knowledge solution will be developed, probably in slightly different directions, by others. It is because knowledge solutions are intrinsically open-ended that they can be adapted, modified and improved in different contexts by firms with a different constellation of human and financial resources. When future innovations are based upon a knowledge solution, even 'first movers' can face the prospect of an unanticipated competitive threat arising from some quarter or other. This is perhaps an uncontentious formulation but what is less well understood is that the knowledge solutions arise as a direct result of the competitive environment that firms have to operate in. And, as has been noted, competition can take two forms.

Static and Dynamic Competition

As Hayek, the doyen of the Austrian School, has noted, at any given time competition between firms, too, operates simultaneously at the level of both static competition and dynamic competition.[4] The presence of static competition drives a firm to search for efficiency gains by relentlessly trying to increase the

efficiency with which existing resources are allocated. At this level, the discovery process often involves a degree of R&D activity, sometimes involving universities, as firms seek to improve the industrial processes they have adopted and the performance characteristics of the products that they currently make. The result is a stream of incremental innovations that arise within the framework of a previously chosen technology set, within what has been described as a design configuration.[5]

It is not noted often enough that firms are often at their most efficient when they are competing *within* a design configuration that a group of individual firms have 'agreed' upon as possessing fruitful lines of development. For example, the delivery of music through laser-based technology and the medium of the CD is the currently accepted way to provide high fidelity music. Most firms in the sector have accepted this, have adopted the relevant technology and sell products which compete with one another in terms of slightly different sets of performance characteristics within the framework of what is possible with that technology. As is well known, in a regime of static competition, markets operate to choose amongst products produced within an 'agreed' design configuration but because firms differ in the efficiency with which they utilise their resources, there emerges in each sector, a hierarchy of firms distributed about what is sometimes referred to as 'average best practice'.

Under dynamic competition, things are very different. Dynamic competition also launches a discovery process but with different characteristics. Dynamic competition operates at one remove. It launches a search for new design configurations—novel combinations of scientific ideas, technologies and potential market opportunities—that might provide alternate bases for the survival of the firm, should its existing technology set—its current design configuration—be undermined by innovations from one quarter or another. In other words, dynamic competition launches the sort of search behaviour that firms must undertake to guard against the possibility that from somewhere a knowledge solution will arise which might render their current technological base and, more critically its specialised work force, obsolete. To continue with the previous example, the CD has displaced vinyl records and magnetic tape systems, but for how long? The CD is currently being challenged not only by new developments in older technologies—vinyl long playing records are enjoying a boom—but also by new technologies—the recordable mini-disc, the Internet and perhaps other technologies whose development potential is now only vaguely perceived. But since firms in the music industry do not know what these knowledge solutions will be or whence they may arise, they deal with this type of risk by participating in joint activities, often joint research activities. To accomplish this, they join networks, enter alliances and form partnerships of various kinds.

In terms of a search process, these competition-induced collaborations form complex problem-solving sites. Solutions are pursued collaboratively, involving many participants, and, paradoxically, often involve competitors. Under dynamic competition, markets still operate; not to choose between products for there are none yet, but between research groups. Because the performance of each group depends upon its composition as well as the resources available to it, groups differ in their creativity and in the effectiveness with which they can translate the results of their work into their respective firms. It is, therefore, of the utmost importance for firms which, and how many, research collaborations they join, and how long they persist as members of a particular grouping.

Radical innovation, then, is driven not primarily by static but by dynamic competition. It is the intensification of dynamic competition that is driving the current proliferation of collaborative problem solving sites. The evidence for this is unequivocal. For example, the numbers of industry–industry collaborative ventures has been expanding exponentially across a large number of sectors for many years now and, not infrequently, they are committed to the pursuit of long-term research objectives.[6] Of course, some of the human resources for these collaborative research ventures are drawn from the employees of firms, but they also make use of the expertise available in the, increasingly global, socially distributed knowledge production system and that includes universities.

Contextualisation, Trading Zones and Transaction Spaces

Though competition-induced collaboration is ubiquitous in both academic and industrial research, the performance of collaborating teams is neither inevitably effective nor an automatic process. It may be helpful, therefore, to describe, however briefly, what may be going on inside the multitude of collaborative arrangements that make up the manifold 'contexts of application' that characterise both Mode 2 research and competition-induced collaboration. To advance, one needs to adopt a different perspective.

In the first section of this paper, Mode 2 knowledge production was described in terms of a number of characteristics which when they appeared together had a degree of coherence which justified labelling them as a new mode of knowledge production. Framed in this manner, Mode 2 was viewed, as it were, from the side of the research process. The same set of practices can also be viewed from the side of society, as an adjustment of existing (Mode 1) research practices to broadly based social and economic imperatives for research-based solutions to a range of complex problems that extend well beyond the bounds of any discipline. This adjustment can be expressed as a response of researchers, generally, to the 'reverse' communications from society. Mode 2 research can then be distinguished from Mode 1 in terms of its openness to this communication and the extent of social participation in the research process. To put the matter slightly differently, Mode 2 is a mode of knowledge production that is more contextualised, more responsive to a wider array of inputs, than Mode 1. The notion of contextualisation directs attention to the openness (or otherwise) of both science (and its institutions) and industry to the needs of society. Although he doesn't make use of the notion of contextualisation, a similar point has been made by Nelson in his extension of the notion of selection environment from a narrowly economic pre-occupation with prices and sales volumes to include non-economic developments such as the emergence of regulatory regimes which also act to shape technological trajectories.[7] To the extent that this reverse communication is averted to, it must lead to the production of a new kind of science, because it will be altering what problems university and industry-based scientists consider it worthwhile working on, how, and with whom. A number of things follow from this shift of perspective.

First, different degrees of contextualisation can be distinguished: weak, middle range, and strong contextualisation; each reflecting the strength of the response of the relevant research community or problem solving team to the reverse communication. Thus, in weak contextualisation, society speaks back largely through the voices of its established institutions that identify experts who attempt to interpret social concerns for the wider society in terms of scientific priorities and

research programmes. Paradoxically, most government-funded research programmes can be categorised as weakly contextualised because, in them, economic and social demands are still communicated indirectly, often through the filters of bureaucracy and the dominant institutions of science and industry. Contextualisation in the middle range is the home transaction spaces, about which more later. Finally, in strong contextualisation, communications not only from experts but also from the wider 'lay' society enter directly into the identification and formulation of problems and issues. Each degree of contextualisation—from weak to strong—describes a mode of knowledge production which depends, more or less, on the functioning of transaction spaces.

Second, to understand the function of transaction spaces it can be helpful to begin from the more familiar notion of a hybrid forum. Historically, the idea of a hybrid forum referred to a socially constructed 'space' where the risks associated with certain technological developments could be debated. These were the public spaces where, for example, the safety of certain types of nuclear reactors, or, in environmental science, the rate of global warming, generated sufficient public concern to provoke governments into establishing a forum comprising technical experts, policy makers and, in some cases, concerned citizens. The involvement of a range of participants is the meaning of the word 'hybrid' in this context. Such fora are now commonplace and most governments consider them as essential elements in involving the public in any scientifically or technically contentious issue. But, they are largely still creations of institutions whether they be international bureaucracies, governments, or lobby groups.

Third, in these fora important new knowledge is often generated. In particular, the experience of working in hybrid fora has led to the widespread recognition that interesting and challenging science can be produced outside disciplinary structures, can give rise to changes in university curricula and, hence, lead to the transmission of new kinds of scientific knowledge. This is well illustrated in the rise of the environmental sciences to the status of a respectable academic subject of both teaching and research. It is possible, therefore, to regard some hybrid fora as among the early manifestations of contextualisation in the middle range. But, the increasing openness and permeability of society's major institutions has also allowed the emergence of a growing number of other, less formally constituted 'transaction spaces' in which various kinds of participants, with different interests and outlooks can, and do, come together.

Fourth, while contextualisation takes place, initially in transaction spaces, the process is far from automatic. Rather, the challenge is to find ways to allow experts and others, each of whom may inhabit different social worlds, to interact effectively so as to be able to transform an issue or problem into a set of common understandings upon which a coherent research programme might be based. Such transaction spaces are essential entities if cooperation is to be promoted and consensus generated because they provide important 'sites' in which still tentative, and as yet inadequately institutionalised, interactions can take place. However, within any transaction space these interactions are more than sets of random encounters.

Genuine transaction spaces recall some of the essential features that the historian of science, Peter Galison, has described for the 'trading zones' he came across when analysing the history of nuclear physics in the twentieth century.[8] In this work, we are made to encounter *within the disciplinary structure* of one sub-field the fascinating exchanges and intense collaborations between three sub-cultures of

the nuclear physics community—theoreticians, experimentalists and engineers (who build the machines used in nuclear science). These traditions remained intact, preserved inside the collaboration, while the co-ordination of exchange took place around the production of the two competing instrument cultures of 'image' and 'logic', which ultimately joined. Similar kinds of exchanges can take place between two competing design configurations. For example, the VHS and Betamax magnetic tape systems for recording television programmes competed with one another initially; though VHS triumphed in the market, in this case the final design configuration was not some 'combination' or synthesis of the two systems as was the case in nuclear science.

Taking his lead from anthropological theories, Galison observes how 'the often asynchronous exchanges between the various sub-cultures of physics can be compared to the incomplete and partial relations which are established when different tribes come together for trading purposes'. Nothing in the notion of trade presupposes some universal notion of a neutral currency. Quite the opposite: much of the interest in the category of trade is that things can be co-ordinated (what goes with what, for what purposes) without reference to some external gauge. 'Each tribe may bring to this interaction and take away from it completely different objects as well as the meanings attached to them. An object which may have a highly symbolic or even sacred value for one tribe may represent an entirely banal or utilitarian object for another. Nevertheless, interaction and trade are possible and actually take place—to the obvious benefit of all because, if this were not so, dialogue would have ceased.'[9] Trading may also give rise to the emergence of contact languages, like 'pidgin', as a means of communication which is inevitably incomplete and truncated. Galison's insight was that physicists and engineers were not engaging in translating knowledge from one sub-culture to another as they pieced together their microwave circuits, nor were they producing 'neutral' observation sentences. *They were working out a powerful, locally understood language to co-ordinate their actions.* Despite obvious limitations, some kind of understanding and exchange does occur in such situations.

For Galison, then, the crucial question was not 'how different scientific communities pass like ships in the night'. Rather he was struck by the diversity of participants in this specialised sub-field of physics: cryogenic engineers, radio chemists, algebraic topologists, prototype tinkerers, computer wizards, quantum field theorists. Similar diversity can be found in the search for new design configurations These searches often involve industry–industry as well as industry–academic collaborations. The question to be answered, then, was how these participants manage to speak to one another at all.

As an example of work across boundaries in an industrial setting, consider the case of the mini-computer developed by the Digital Equipment Corporation (DEC) which has been so brilliantly described by Kidder in his book, *The Soul of a New Machine.*[10] Here, what has been described in this paper as a transaction space was largely internal to the corporation but its boundary was a highly permeable one. The author describes a competitively driven process of discovery that would lead eventually to a new design configuration that might underpin the manufacture of the new computer, though neither the configuration itself nor the path to its discovery were known. But, as the narrative makes clear, there was little agreement, initially, on what the configuration might be like or what skills might be required to discover it. In the process of 'discovery', expertise of many different stripes collaborated in the search. These included engineers and computer programmers,

of course, but also logicians, mathematicians, and solid state physicists as well as finance and marketing personnel, among others. Some of the participants in this transaction space came from universities; others from elsewhere in the socially distributed knowledge production system that has been described above. Not many worked on the project throughout its duration, for as the project evolved, the composition of experts shifted as new, unanticipated problems emerged. Finally, the 'management' of the project, was, seemingly, the responsibility of one individual, whose function is perhaps better described as a knowledge broker than either as a manager or an entrepreneur. He it was who facilitated the collaboration that led to the development of the common language necessary to develop the design configuration and who moved the experts in and out of the transaction space as the project developed. Being a knowledge broker is a subtle art but it can often involve telling highly respected experts that their role in the collaboration is at an end. As Kidder makes clear, the participants to the process, including university researchers, put up with this somewhat 'rough' management practice because they knew that many important and intellectually challenging problems would be addressed on the way from the original ideas to a final design configuration and that they could not afford to be absent from the evolving 'conversation'.

This example provides an instance, and no doubt there are many others, of the strategic importance of managing complex problem solving within an organisation, but making use of experts drawn from the greater socially distributed knowledge production system. It also illustrates what complexity theorists refer to as the co-existence, in a single organisation, of areas of stability and instability, for it was undoubtedly the case that DEC had to develop and improve its other product lines simply to remain strongly enough in business to be able to fund major new developments. The point is that the strategy and style of management necessary to improve a product is vastly different from those that are necessary to develop a new one, particularly where, as in the case of DEC, it is not clear just what 'shape' the new product would have. It would be interesting to discover how DEC balanced these two necessary but very different strategies within the same organisation. This might be a more difficult task than it might appear at first sight, because it has been argued by some organisational theorists that the strategies necessary to promote the creativity required to find new design configurations are barely acknowledged inside the organisation, so much so that not infrequently these activities have to be carried on surreptitiously. The current dominant discourse of rational planning and outcomes management, etc., it seems, is a well-entrenched 'mindset' which organisations find difficult to displace. As many management researchers have observed, creative people have always found ways to 'work around it'!

To conclude this section, it should be noted that in both of the examples—nuclear physics and the search for a design configuration for a new computer—some 'trading' takes place in what have been denoted above as transaction spaces. As in the case of trading zones, the idea of 'transaction' implies, first, that all partners bring something that can be exchanged or negotiated and, second, that they also have the resources (scientific as well as material) to be able to take something from other participants. Of course, the meanings attributed to exchanged objects may differ greatly for different participants. But the success of these exchanges depends upon each participant bringing something that is considered valuable by someone else—whatever that 'perceived' value might be. Over time, participants typically return to their 'home bases' with their gains.

Equally, in typical Mode 2 fashion, they may use the links they have established and knowledge exchanges they have experienced by collaborating with others as the base for joining other collaborations. In this way a pattern of development might emerge in which the original participants never return to their home base but rather pursue, in a trans-disciplinary way a quite different trajectory of scientific and technological inquiry.

It has been suggested that the research practices that characterise Mode 2 knowledge production can be seen either from the side of research or from the side of society. The notion of transaction space makes the double aspect of this process more transparent, because transaction spaces become visible as the sites where the first tenuous interactions—conversations—between society and science take place. They are spaces (both symbolically and very concretely) where potential participants can decide what might be exchanged or traded and also establish the lines of communication necessary to sustain discussion of potential to the point where constraints become visible. Of course, if the constraints are too severe the transaction space may disintegrate, but, through further interaction, ways may be found to overcome constraints and when this happens a more robust research activity will emerge. As has been indicated, the growth in the numbers of transaction spaces, some of which will persist while others will be transitory and temporary, is one of the characteristics of Mode 2 knowledge production.

In sum, the idea of hybrid fora, together with the function of trading zones drawn from anthropological research, can be extended to the notion of transaction spaces; spaces where different types of expertise, outlooks and interests come together and through local exchanges of various kinds may be able to develop a language within which to pursue a common research agenda. 'Local', in this context, is meant to imply that the area of agreement is limited and, by agreement, other issues are for the moment left untouched.

Managing Research at the Boundaries

There is a further insight that can be had from Galison's work. He notes that:

> (a) trading zone is an intermediate domain in which procedures could be coordinated locally even where broader meanings clashed . . . The work that goes into creating, contesting, and sustaining local coordination is at the core of how local knowledge becomes widely accepted. In other words, '*rather than depicting the movement across boundaries as one of translation (from theory to experiment, or from military to civilian science, or from one theory to another)' it may be more useful to think in terms of work* ***at*** *boundaries*, where local languages grow, and sometimes die in the interstices between sub-cultures (italics mine).[11]

In general, the idea of trading at boundaries within transaction spaces captures very well what is actually taking place in the many research problems that characterise what in Mode 2 has been called research in the context of application. To be effective, these research collaborations need to be more than merely concatenations of experts who bring specific items of 'information' to the group. Rather, progress towards the resolution of a problem requires the generation of a 'local' framework of understanding, and this, in turn, requires the generation of a new common language amongst the participants. As Galison has observed, the development of this common language is neither a matter of the imposition of a

particular set of ideas, techniques or methods by a dominant participant, nor the lowest common denominator of all the views possessed by them, but it is something new. It is a synthesis of these elements derived from what he calls 'trading' at the boundary of the different social worlds represented in the collaboration. The empirical evidence of such trading and the synthesis it brings about is manifest, concretely, in the emergence of a new language which attests to the fact that sufficient common understanding has been achieved to allow the participants to continue collaborating. As Star *et al.* have observed, it 'is not normally appreciated just how often it is the case that the objects around which scientific work is organised require the participation of experts who inhabit multiple social worlds'.[12] All science, it seems, is involved in the search for new design configurations, not only Mode 2 science, but Mode 1, as the example of nuclear science presented above indicates, also requires inter-sectoral work. In such work, it is not helpful to try to separate the new language from the collaboration that gives rise to it. Metaphorically, they constitute the obverse and reverse sides of the same coin. A new language, it should be further noted, is not the 'discovery' of some pre-existent language but a form which did not exist previously and has emerged as a result of the collaborative process itself. It may not be taking things too far to say of the new language, and the collaborative form within which it arose, that they co-evolve; that they both sustain, and are sustained by, one another.

In the research literature around this topic, the question has arisen about whether these collaborative processes are spontaneous ones; the outcome of the propensity for self-organisation which has been identified as characterising all complex systems. The idea of work at the boundaries whether it be at the boundaries of the sub-cultures of physics, of disciplines, of technologies, or of the other manifold forms of expertise that can be attracted to a complex problem has a certain resonance with the notion of creativity at the edge of chaos which has emerged, and is currently enjoying some celebrity, within research in the complexity sciences. Of course, self-organisation has not yet been fully verified in human systems. Its use has so far been as a possible analogy with non-linear physical systems which exhibit emergent forms apparently spontaneously, under certain conditions. It is a further question, then, whether this notion applies to human systems. Nonetheless, as a consequence of research in the complexity sciences, the analogy has become imperative and organisations are now encouraged to push their organisations to 'the edge of chaos', because these regions of instability are (whether analogically or metaphorically conceived) believed to be the natural homes of creativity in organisations. In this view, areas of organisational instability are correlated with radical innovation while areas of organisational stability are correlated with incremental innovation. To use the complexity sciences, heuristically, in this way can be helpful for it is clearly an advance to appreciate that, within a particular organisation, the search for radical innovation needs to be handled differently from the process of incremental innovation.

All very well, but what might it mean to treat each area differently? What would managers do differently in handling areas of stability or instability? As has been suggested above, it is perhaps an advance in understanding to grasp that areas of instability tend to require more attention to boundary work than areas of stability. But the question persists, 'If that is the case, what needs to be done differently in the two areas?' To take an extreme example, for some management researchers, the attractiveness of the notion of transaction spaces as the sites of creativity and innovation may be that these 'emergent forms' seem to be the

outcome of spontaneous self-organising processes rather than the unfolding of some inherent tendency or teleology. If true, then areas of instability, of innovation and creativity, emerge without a plan and, therefore, may need minimal managerial encouragement or support. To some this is a very appealing notion because it would seem to lend credence to the idea that innovation is the outcome of the unconstrained operation of the forces of creativity. Academics, in particular would also approve of this idea because it supports their deeply held conviction in the intrinsic value of unfettered inquiry as the only 'sure' route to discovery, albeit in the long run.

We can take another, perhaps equally extreme, example. That sector of academic management science that is committed to systems thinking would not find it easy to accommodate within its frameworks the notion that some areas within an organisation should be free from the constraints of planning and budgetary control. On this view, the function of management is to identify objectives, allocate resources and evaluate outcomes. This view is clearly better adapted to behaviour in areas of stability where process and product development have already become routinised. Nonetheless, tough-minded managers can be expected to favour the extension of routinisation throughout their organisations as the rational (safest?) way to proceed.

These two examples are, admittedly, extreme ones, but what they expose is that the current mindset of both managers and researchers in the academic community that advise them has found it extremely difficult to deal with the organisational requirements of areas of instability—that is, with dynamic competition and the search processes that it drives. On the one hand, it is not much help for managers to be told that the current dominant discourse of organisational theory is unable to deal with innovation; on the other hand, it is intellectually unsatisfying for management researchers to have to acquiesce to the notion that a key driver of the innovation process may arise from the spontaneous self-organising tendencies of complex systems. For the former it is a source of anxiety while, for the latter, it may amount to a euphemism for the abandonment of management control over the innovation process altogether. Both are trapped, it seems, between the mindset of managers who want to demonstrate control over the organisations they run and the desire of researchers in the academic community devoted to business research that try to support them in their uncertainty by promoting methods that apply to only part, and perhaps not the most important part, of the organisational challenges they face.

Can any progress be made? The notion of 'work at the boundary' which has been adumbrated above may perhaps indicate a way out of this dilemma. The thrust of the argument so far has indicated the importance of finding common languages in transaction spaces that provide the common frameworks of understanding that allow effective collaboration between individuals that occupy different social worlds. But it certainly does not demonstrate that these outcomes can be obtained without some managerial imagination or effort. There is nothing to indicate that effective collaboration in transaction spaces, though they are emergent forms, 'just happen'; that emergence and functioning come as a 'surprise' to everyone. As with every other from of human activity, to work effectively, even at the boundaries, requires a degree of both support and control. The point is that this mode of management cannot simply be an application, perhaps not even an extension, of the current dominant discourse on business research to the extent that it remains so deeply rooted in systems thinking.

To manage innovation—areas of instability—a new mindset is required and it is to be expected that those who must deal with the pressures of the real world will be impatient with such a notion. Such impatience is a manifestation of a failure to grasp the truly experimental nature of the innovation process. Briefly stated, uncertainty in relation to outcomes is of the essence of any experimental situation. It is, therefore, a frank denial of the recurrent need for a continual supply of fresh insight for managers to expect, or management researchers to provide, a set of rules for managing areas of instability.

Clearly, such a major shift in approach cannot be accommodated by simply importing the language and practices of the current dominant discourse. Yet, as Lacey has observed, this tends to be what is done.[13] If a new framework is required to 'make sense' of what is going on in an organisation then it must be expected to be different from the dominant discourse, and there is no gainsaying that fact. The burden of this paper has been to argue that a way forward lies in thinking of innovation in terms of encouraging, within or across existing organisations, the emergence of transaction spaces that operate at the boundaries of established activities. Strategies to encourage this need to realise/accept that when uncertainty and complexity are endemic, as they are in research and innovation, they cannot be excised by imposing strategy guidelines that ignore this fact. Strategies that accept the prevalence of complexity and uncertainty need to recognise that this implies a certain amount of irreducible redundancy; that novel organisational forms need to be discovered; that criteria to assess and reward group creativity need to be developed; and, perhaps most important of all, that collaborative creativity needs to be 'managed', not least in terms of reducing the anxiety that researchers face when they have to operate 'undercover' in transient collaborative frameworks. As has been indicated above this is precisely what Mode 2 knowledge production is all about.

Naturally, government's tend to be wary of supporting programmes that depend upon these kinds of factors and much prefer the apparently more rigorous language of objectives and outcomes. Nonetheless, both policy makers and strategic analysts have to accept that innovative organisations need both stability and instability, and each has its own criteria of effectiveness. Failure to acknowledge this will surely lock research based organisations, and possibly countries as well, into forms of behaviour and practice that, in the long term, will render them vulnerable to new ideas and practices developed elsewhere. As in industry, so in government, the new mindset requires an acknowledgement that science and technology, on the one hand, and policy or strategic management, on the other hand, must mutually shape one another.

Concluding Comments

The significance of boundary work is that it can lead to the formation of transaction spaces and that these can be depicted as emergent forms. As emergent, these forms constitute areas of organisational instability. It is true that they may be instances of self-organisation and that they may emerge according to some schedule of probabilities. But it does not follow from this that their emergence is either automatic or that it lends support to current forms of liberal economic ideology. Rather, work in areas of organisational instability also needs to be facilitated and 'mangaged', but in these areas, the appropriate style of management is different from the one that pertains in areas of stability. The change is a profound

one. In fact, managing areas of instability seems to require approaches that are incompatible with the dominant discourse of much research in business management, for all that it may formally persist in any organisation. The notion of a new mindset is intended to take us beyond this dominant discourse to something else; to an, as yet unknown, X. It is the burden of the argument in this paper that the to-be-discovered X lies beyond current ways of thinking about planning and resource allocation that have been developed to handle regimes of static competition. As always, the way forward is to begin empirically and examine what managers actually do when confronted with the imperatives of dynamic competition and how individuals in organisations actually respond to the uncertainty that is so generated.

In summary, to remain innovative organisations need to devote at least part of their effort to promoting creativity. This is as important for universities as it is for industry. Researchers in both environments know this and to maintain their creative performance they have increased enormously the numbers of collaborative arrangements in which they participate. Through these forms, work in transaction spaces at boundaries is encouraged; whether it be between departments within a single organisation or between groups located in different organisations. Without much in the way of organisational change or support, so far at least, this strategy has been adopted by researchers everywhere. It is a style particularly appropriate to the more open forms of knowledge production that have been described herein as Mode 2 research. As a new mode of research its research practices are supported by a range of emergent forms, the facilitation and management of which set similar problems for both university leaders and industrial managers.

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