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From 'ivory tower traditionalists' to 'entrepreneurial scientists'? Academic scientists in fuzzy university-industry boundaries

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From ‘ivory tower traditionalists’ to ‘entrepreneurial scientists’? Academic scientists in fuzzy university-industry boundaries

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Abstract

Growing intensity of university-industry ties has generated an intense debate about the changing norms and practices of academic scientific work. This study challenges the protagonists’ views on the emergence of a dominant market ethos in academic science and growing influence of the ‘new school’ entrepreneurial scientists. It argues that academic scientists are active agents shaping the relationships between science and business, and shows continued diversity in their work orientations. Drawing on neo-institutional theory and the notion of ‘boundary work’, the study examines how scientists seek to protect and negotiate their positions, and also make sense of their professional role identities. It identifies four different orientations, the ‘traditional’ and ‘entrepreneurial’, with two hybrid types in between. The hybrids are the dominant category and are particularly adept at exploiting the ambiguities of ‘boundary work’ between academia and industry. The study is based on 36 interviews and a survey sample of 734 academic scientists from five UK research universities.

Keywords:
Academic scientists; academic capitalism; entrepreneurial university; knowledge commercialisation; boundary work; institutional theory; sociological ambivalence; university-industry collaboration

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INTRODUCTION

The growing intensity of university-industry ties has been a profound organisational change that has shaped the work experiences of academic scientists over the past two decades. According to some authors, academic science is undergoing transformation in response to the growth of an 'entrepreneurial academic paradigm' that stresses knowledge capitalisation (Clark 1998; Etzkowitz, et al. 2000). The UK government's science and technology policy since the early 1990s has called upon universities to play a more central role in supporting economic growth, and has used various policy schemes to promote knowledge transfer towards industry (DTI 2000; HM Treasury, et al. 2004). At the same time, universities themselves have become willing actors in the exploitation of research results to boost their income and adapt to a more competitive environment (Henkel 2007; Slaughter and Leslie 1997). As a consequence, there has been a growth in the variety and volume of collaboration between university and industry, and an increased institutional emphasis on using commercialisation of intellectual property as a means for revenue generation (D'Este and Patel 2007; Siegel, et al. 2007).

These developments have aroused intense debates about the changing relationship between academic scientists and the marketplace, and the consequences of the increasingly blurred boundaries between science and business for the norms and practices of academic scientific work (Owen-Smith and Powell 2001a; Trowler 2001; Vallas and Lee Kleinman 2008). Some scholars view the institutional transformation in a positive light and stress the growing convergence between academia and industry. They describe the emerging structures as a 'new mode of knowledge production' (Gibbons, et al. 1994) or 'triple helix' (Etzkowitz and Leydesdorff 2000) that links the university, private industry and government together in a productive relationship. Authors in this camp herald the arrival of a new class of 'entrepreneurial scientists' who integrate academic research with its commercial exploitation. By contrast, other researchers are deeply critical of close university-industry ties and warn of the normative and institutional risks associated with academic entrepreneurialism (Beck and Young 2005; Hackett 2001). Slaughter and her colleagues use the term 'academic capitalism' to describe the encroachment of a profit motive into academia (Slaughter and Leslie 1997; Slaughter and Rhoades 2004). These critics emphasise growing conflict of values and crisis of role identities experienced by academic scientists, and the erosion of academic freedom and autonomy.

Despite the on-going debate, our understanding of the 'new knowledge regime' and its consequences on academic scientific work has been limited by the narrow empirical focus of most of the literature and its oversimplified theoretical assumptions about the underlying process of change. Empirically, much of the existing research

has focused on the intellectual property regimes (e.g. patenting, licensing or participation in entrepreneurial start-ups) that shape the work situations of university scientists (see, for example, special issues of *Research Policy, 2008;* and *Industrial and Corporate Change*, 2007). Many of these studies have largely neglected the deeper cultural-cognitive aspects of the change process underlying the formal arrangements. Theoretically, there is a tendency among many authors to view the shifting boundary between academia and private business as an institutional change that occurs as a linear historical process in which the old institutional logic of academic science is under attack (Beck and Young 2005; Hackett 2001) and will be eventually replaced by the new logic of entrepreneurial science (Etzkowitz, et al. 2000). Both the 'new knowledge production' and the 'academic capitalism' perspectives are built on the presumed inevitability of the entrepreneurial university. Their analysis takes place at a high-level of aggregation and generalisation. This approach all too easily obscures the internal diversity in academic scientific work (Tuunainen 2005), and the complex dynamics of organisational change that permit the co-existence of contradictory institutional logics (Murray 2006; Smith-Doerr 2005; Vallas and Lee Kleinman 2008). More importantly, it fails to take account of the strategic role of actors, namely scientists themselves, in shaping change.

The study presented in this paper seeks to go beyond these limitations by adopting a micro-level perspective to examine how the shifting boundary between university and industry is experienced and can be shaped by academic scientists themselves. The analytical framework draws on the theoretical insights of the new institutional school of organisational change which highlights actor choice and strategic action in shaping change (Barley and Tolbert 1997). The sociology of science literature provides the main concepts and micro-theories for interpreting the strategic responses of scientists to the changing work environment. The analysis stresses how scientists exploit the 'sociological ambivalence' (Merton and Barber 1963) of their 'boundary work' (Gieryn 1983; 1999) to defend and negotiate their positions, while at the same time seeking to acquire critical resources in pursuit of their career goals. The evidence presented shows that scientists are active agents shaping the relationship between science and business, and have developed different modes of engagement with the emerging knowledge regimes. While some adhere to the 'traditional' norms of basic science and resist the encroachment of commercial practices, others exhibit an 'entrepreneurial' orientation and partake in the realms of both science and business. Between the two polar positions of the 'old' and the 'new', the majority of the scientists display 'hybrid' orientations and are particularly adept at mapping out their own social spaces for strategic manipulation at the fuzzy boundaries between science and business. This study challenges the protagonists' views on the emergence of a dominant market norm in academic science and provides evidence of continued diversity. The empirical evidence is based on 36 in-depth individual interviews and a survey sample of 734 academics scientists from five UK research universities.

The paper is structured as follows. Section two outlines the analytical framework and discusses the main concepts employed for the study. Section three describes the research methods and data. This is followed by an analysis of the scientists' orientations in section 4. It identifies four orientations, placing the scientists on a continuum defined by two polar types, the 'traditional' and 'entrepreneurial', with two mixed types, the 'traditional hybrid' and 'entrepreneurial hybrid' situated in between. Section 5 examines how the differently positioned scientists use varied strategies of

boundary work to defend and negotiate the boundaries between science and business, and also to make sense of their professional role identities. The final section discusses the implications of the study and the value of adopting an actor-oriented perspective.

SCIENTISTS AS STRATEGIC ACTORS IN SHIFTING UNIVERSITY-INDUSTRY BOUNDARIES: 'SOCIOLOGICAL AMBIVALENCE' AND 'BOUNDARY WORK'

Neo-institutional theorists treat the change and reproduction of institutions as a dynamic, ongoing process in which actions and institutions are recursively related (Barley and Tolbert 1997; Oliver 1991). Oliver (1991) argues that individuals and organizations do not simply conform to institutional pressures but respond positively to them and in some cases modify them. She proposes five types of strategic responses to institutional process, from passivity to increasingly active resistance: acquiescence, compromise, avoidance, defiance, and manipulation. Institutions may also vary in their normative power and their effect on behaviour, depending on how widely and deeply institutions are accepted by members of a collective (Tolbert and Zucker 1996). Moreover, actors can take different orientations with regard to the social structures in which they are situated and develop different modes of engagement (Duberley, et al. 2006; Mouzelis 1989).

It is also possible for an institution seem to change at the formal policy level without concomitant changes in cultural norms at the organisational or individual levels. Aldrich and Fiol (1994) distinguish between socio-political legitimacy where practices or rules are approved or mandated by the state, and cultural-cognitive legitimacy, in which ideas are more subject to actor interpretation. Moreover, these two component parts need not be in congruence as we often assume. A study by Colyva and Powell (2006) on the institutionalisation of academic entrepreneurship in the US shows that new practices can be more or less legitimated, and they may fail to become deeply cognitively embedded despite apparent formal compliance. Moreover, the new practices that are becoming legitimated can also be transformed in the process as actors interpret them and imbue them with new meanings according to the institutional logics of their specific domains or strategic goals. As DiMaggio (1997:265) notes, institutions or culture are 'complex rule-like structures that constitute resources that can be put to strategic use'. Murray (2006), for instance, examines how geneticists in the US resisted and accommodated 'patenting' and, in the course of doing so, they re-interpreted the meaning of patenting by treating it as an alternative currency for building academic reputation, and also used it as a means to exclude unwanted commercial intrusion. Thus, actors have the leeway and flexibility to use their existing relations and understandings to incorporate, transform, or resist new practices. Hence, our understanding of the dynamics of institutional change will need to recognise the ambivalence inherent in the structural conditions of change as well as the responses of actors (McLoughlin, et al. 2005).

Early research in the sociology of science highlights the sociological ambivalence of scientists and their active agency role in defending their positions in response to external challenges. Merton's (1957) early formulation of the norms of basic science as characterised by universalism, communism and disinterestedness regulated by a scientific-community has been criticised by some as overly idealised, and ignoring

both the practical realities of scientific work and the day-to-day negotiation among scientists to secure resources for their work (Latour and Woolgar 1979; Mitroff 1974). His later work (Merton and Barber 1963; Merton 1976) on the notion of 'sociological ambivalence', together with Mitroff's (1974) concept of 'counter-norms', suggest that the role of scientists reflects a dynamic interaction between countervailing orientations to dominant norms and subsidiary counter-norms. For example, scientists may portray their research as either basic or applied, and the boundary between production and exploitation of knowledge may be clearly demarcated or blurred depending on the demands of the situation and external challenges encountered. Such 'sociological ambivalence' may generate inner conflicts and tensions among scientists (Hackett 2005). However, it serves also as a useful social device for scientists to cope with the contingencies that they face in trying to fulfil their functions. Mulkay (1980) argues that sociological ambivalence provides scientists with alternative cultural resources which they may use for legitimating work boundaries and defending their positions in different contexts.

Gieryn (1983; 1999) coined the term 'boundary work' to denote the active agency role of scientists in drawing and redrawing the boundaries of their work to defend their autonomy and secure resources in pursuit of professional goals. He stresses the power of scientists' interpretative strategies in constructing a space for science for 'strategic practical action'. His historical analysis of scientists' efforts to preserve autonomy and enlarge resources for research showed that the boundary between basic and applied research was clearly established when the scientific community wanted to protect their professional autonomy and ensure that basic research was free from government interference. However, it often became obscure, if not dissolved, when scientists sought to secure increased resources and public support for research. Gieryn (1983: 789) refers to 'boundary work' as an ideological style found in scientists' attempt to present their social and collective image to the external world in their struggle for autonomy and public support. This concept has also been widely used to examine the occupational demarcation problems of professionals, and the strategies that they use to defend the content of their work and institutional arrangements that undergird their practice (Lamont and Molnar 2002:177-8).

While much of the existing research applying the concept of boundary work has focused on its external, socio-political aspect (e.g. Calvert 2006; e.g. Lövbrand 2007), this study draws attention also to its inner, socio-cognitive dimension in relation to scientists' professional role identities. Work boundaries and role identities are intertwined, and challenges to external work boundaries may threaten stable role identities (Ashforth, et al. 2000; Kreiner, et al. 2006). Beck and Young (2005) argue that the contemporary transformation in the relationship between academia and the marketplace presents a major challenge not only to the external conditions of academic work, but more fundamentally, to the core elements of academic professional identities. The professional role identity of academic scientists has historically been deeply rooted in a distinctive scientific community marked by strong external boundaries and a special relationship to knowledge production (Henkel 2005; Kogan 2000). This self-regulative bounded world is associated with the Mertonian norms of disinterestedness and communism, traditionally upheld by the scientific community as the default ideals that promote the free pursuit of knowledge. Although scientists do not always adhere to these ideals in practice, they have great normative significance for the community and serve to underpin its professional

autonomy and role identity. The increased penetration of the marketplace into academia and commercialisation of knowledge pose a challenge to this professional ideal. Some authors point out that a scientist's decision to go down the commercialisation path potentially involves a role transition and inner sense-making process akin to managing multiple role identities (George et al 2005; Pratt and Foreman 2000). What strategies, then, do scientists employ to negotiate their work boundaries and role identities as they embark on commercial roles? How do they reconcile the tension between the contradictory logics of science and business?

The study presented below will explore these questions, focusing on the external as well as internal aspects of scientists' boundary work. It will examine the attitudes and responses of scientists to university-industry ties, and how they use varied strategies of boundary work to manage the changing relationship between the two sectors, and make sense of their professional role identities.

RESEARCH METHODS AND DATA

The data on which this paper is based is part of a larger study on the work roles and careers of academic scientists in university-industry collaboration. The study used a combination of in-depth individual interviews and an on-line questionnaire survey, and was undertaken between 2006 and 2007. The sample consisted of academic scientists from five major research universities in the UK, covering the following main disciplines: biological sciences, medicine, physical sciences and, computer science and engineering. Much of the recent debate about research commercialisation has concerned these disciplines. The first stage of data collection involved in-depth individual interviews with scientists engaged in various types of industrial links ranging from traditional modes of collaboration (e.g. collaborative research, consultancy, joint publications, student sponsorships) to direct involvement in commercial activities (e.g. patenting, licensing, and company affiliation or formation). The individuals were identified mainly through CV search on the universities' web sites. A snowball method was also used to obtain additional names. A total of 36 academic scientists were interviewed. It should be noted that this is a selective sample as the majority who agreed to participate in the study had substantive experience in collaborating with industry (22 had been involved in collaborative links and 14 had commercial ties and company formation experience). Thus the sample is skewed towards those with an 'entrepreneurial' orientation. The interviews focussed on the scientists' experiences and attitudes towards industrial links, their motives for engaging in such activities and the ways in which industrial collaboration influenced their work and professional role identities. Each interview lasted for about 75 to 90 minutes, with some lasting for more than two hours. All of the interviews were recorded and transcribed. The distribution of the interview sample by disciplines is shown in Table 1.

Following the completion of the interviews and initial data analysis, an on-line questionnaire survey was implemented. The survey aimed to map the extent of scientists' involvement in industrial links, and examined the experiences and attitudes of a wider population of academics. The web-based questionnaire was e-mailed to about 3,100 academics. The sample population included all permanent academic staff and principal investigators of major research units, covering the disciplines mentioned above. The software used for the survey enabled tracking of the responses and

reminder messages were sent twice to those who did not respond initially. This subsequently yielded 734 responses, giving a 24 percent response rate. This is relatively good for internet-based surveys. There was no significant variation in the response rates among the different disciplines, indicating a degree of consistency in the response patterns (Table 1).

As in the case of the interviews, the responses were likely to be biased towards those more actively engaged in industrial links as these academics might have felt more motivated to respond to the survey. Over two-thirds of the respondents (73%) reported that they had involvement in industrial links over the last ten years, of which 39 percent had involvement in mainly collaborative mode of activities and 34 percent also participated in commercial activities (22% held patents; 12% reported affiliation with start-ups and 10% had formed their own companies). Similar patterns of industrial engagement were also reported in a recent study by D'Estate and Patel (2007) based on a large scale survey of UK academic researchers, supporting the general reliability of this study.

The analysis presented below will draw heavily on the interview data and the survey results where relevant.

Table 1 about here

A TYPOLOGY OF SCIENTISTS: 'OLD SCHOOL' TRADITIONALISTS VS. 'NEW SCHOOL' ENTREPRENEURIAL SCIENTISTS

In contrast to the protagonists' views on the growing dominance of an entrepreneurial orientation, the study finds a great deal of variation in the scientists' responses to university-industry ties. In this section, I develop a typology of scientists to explore their diverse work orientations. This draws on the insights of earlier research on the differentiation of scientists according to their attachment to scientific values and goals (Box and Cotgrove 1966; Toren and King 1982) and a more recent study by Owen-Smith and Powell (2001) on the attitudes of university scientists to research commercialisation. It places the scientists on a continuum defined by two polar types representing the 'old school' traditionalists vs. the 'new school' entrepreneurial scientists at the opposite ends, with two mixed types, the 'traditional hybrids' and 'entrepreneurial hybrids', situating in between. The five key dimensions differentiating the four categories are summarised in Table 2.

Table 2 about here

These dimensions were initially derived inductively from the interviews and later cross checked against the survey data. In the interviews, scientists were asked detailed questions about the extent and intensity of their engagement in industrial links, their motivations and incentives for such engagements, their work roles and professional identities, their attitudes towards academic-industry relations and assessment of the influence of industrial engagements on their research and careers. Those who had been actively engaged in industrial activities were asked to elaborate on the ways in which they managed the boundary relationships and, resolved potential tensions and conflicts. At the end of the interviews, the scientists were shown a card

with the statements describing the four categories (see Appendix) and asked to select one category that best described their orientations. Although not all the scientists saw themselves as falling into 'pure' categories, their dominant orientations could be identified from their responses to the descriptive statements and other questions asked in the interviews. In the data analysis, the scientists' 'self-definitions' were cross checked against their responses to other relevant questions and generally found to be consistent. The classification was subsequently refined and used in the survey where the respondents were asked to select their 'first best' and 'second best' choice of statements that best described their professional orientations (see, Appendix A). The distribution of the responses shows that in the great majority of the cases, the second choice was contiguous to the first which illustrates the consistency of the choices (see, Table A in Appendix). The first choice category is adopted for the quantitative analysis in mapping the scientists' orientations onto other relevant dimensions pertaining to the typology.

The distribution of the interview and survey samples by the four types, and the variation in their engagement in industrial links are shown in Table 3. It should be noted that 22 of the 36 interviewees also responded to the survey which enables cross-checking of the consistency in the classification. Table 4 shows the factors that have motivated them to engage in industrial links

Tables 3 and 4 about here

In this classification, *Type I 'traditionalists'* are characterised by a strong belief that academia and industry should be distinct and they pursue success primarily in the academic arena. Although they may develop some links with industry (e.g. collaborative research, student sponsorships), the main reason for doing so was to acquire financial and other resources to support academic research. Type I scientists typically do not pursue commercial mode of engagement and tend to be suspicious of those who do so.

In contrast, *Type IV 'entrepreneurial scientists'* see the boundary between academia and industry as highly permeable, and they believe in the fundamental importance of science-business collaboration for knowledge application and commercial exploitation. The dominant majority of these scientists had involvement in industrial links and 59% were engaged in commercial activities of one kind or another, with 29% being company founders. The importance of knowledge application and exploitation to these scientists is clearly indicated in the survey where 84% of them agreed that this was an 'important/very important' factor motivating them to engage in industrial links. What also sets this category apart from the other three Types is the relative importance of personal financial gains (Table 4).

Between the two polar types, nearly two-thirds of the scientists surveyed exhibit a 'hybrid' orientation combining elements of both the 'old' and 'new' schools. Hybrids appear to adopt contradictory positions and express paradoxical views about the nature of relationships between science and business. There are two categories of hybrid scientists: *Type II 'traditional hybrids'* share the old school commitment that the boundary between academia and industry should be distinct, while at the same time recognising the need to engage in science-business collaboration for scientific advancement. Two-thirds of them reported having involvement in industrial links over

the last ten years, and just under one-third were engaged in commercial activities. These scientists adopt a pragmatic orientation towards science-business interaction, while maintaining a strong academic identity. Like their Type I colleagues, they pursue industrial links primarily to obtain funding resources to support their research, although knowledge transfer and exploitation was also seen as important by some.

The other hybrid position, described as *Type III 'entrepreneurial hybrids'*, comprises the largest category (39%) of those surveyed. Scientists who fall in this category share the new school belief in the importance and benefits of science-business collaboration, while maintaining the old school commitment to the core scientific values. The majority of the Type III scientists had engagement in industrial links and 42 percent were involved in commercial mode of activities, with 16% affiliated with start-up companies and another 12% being company founders. While Type II scientists were not entirely at ease with commercial endeavours, scientists holding a Type III position perceived such endeavours as largely legitimate and desirable for their scientific pursuits. Besides obtaining funding for research, Type III scientists were motivated by a range of other knowledge, reputational and network building factors in their pursuit of industrial links.

Universities are complex organisations comprising different academic disciplines and departments, and science itself is a disunified endeavour pursued by groupings of experts who are separated from each other by heterogeneous research approaches (Knorr-Cetina 1999). The diversity in scientists' orientations toward science-business links reflects, in part, the different disciplinary norms, history of industrial engagement, and the divergent pressures and opportunities for research commercialisation in the different fields. For example, the survey shows that the traditional types (I and II) have a more conspicuous presence in physical sciences (57%) than in the applied subjects such as engineering and computer science (38%); whereas the entrepreneurial types (III and IV) are more prominent in the latter (62%) than in the former (43%). In subject areas where recent scientific advancement has blurred the boundaries between basic and applied research, and opened up new opportunities for commercial exploitation (e.g biosciences and biomedicine), it is roughly an equal split between the traditional and entrepreneurial types.

However, beyond disciplinary variation, two observations are notable. The first is that all the different types are present within each disciplinary category. This suggests that an academic discipline may influence but does not determine scientists' orientations to industrial engagement. Previous research shows that scientists' early socialisation and work experience can influence their propensity to develop industrial links (Bercovitz and Feldman 2003; Stuart and Ding 2006). The second is that 'hybrids' (Types II and III) are the dominant category (70%+) across all the subjects. Their strong presence suggests that the conventional approach of conceptualizing the outcomes of the institutional transformation in terms of a simple dichotomy of the 'new' entrepreneurial scientists vs. the 'old' traditionalists fails to capture the complex variation in scientists' responses to the shifting academic landscape.

BOUNDARY WORK, PROFESSIONAL AUTONOMY AND ROLE IDENTITY

This section examines how scientists characterised by the different orientations use varied strategies of boundary work to defend, maintain or negotiate their positions.

The analysis will draw heavily on the individual interviews, supplemented by the relevant survey data on the respondents' evaluation of science-business relations (Table 5) and also analysis of the written-in comments provided by 152 respondents, spread widely across the four types.

Table 5 about here

Type I 'traditional scientists': boundary separation and expulsion

For the Type I 'traditionalists', the boundaries between academia and industry are markers of differences between two distinct institutional domains. The distinction between basic and applied research, grounded in different types of organisations, continues to represent a boundary that has meaning and significance for these scientists. The university, according to the Type I scientists, should be the setting for the pursuit of disinterested basic research, while applied work should be done in the commercial setting. A Type I computer science professor interviewed, for example emphasised the importance of differentiating academic research from industrial problem-solving and talked about the need to 'protect' himself and his colleagues from 'the pressure to make a lot of connections with industry'. He believed that 'real academics' should focus mainly on basic research and, those engaged in industrial problem-solving 'are more like scientists in the research and development of big industrial firms', and they 'should not be in the university in the first place.' Another Type I professor, in physics, described one of his colleagues who engaged in applied work as someone who was 'not really an academic' because 'he doesn't write many papers… his aim is to produce instruments…'. These accounts in the interviews were evidently boundary-making in themselves in that the scientists' role identity was intimately associated with the pursuit of basic science in the context of the university. Their definition of who is and who isn't a 'real academic' amounts to a strategy of symbolic expulsion to protect and defend their own academic role identity.

Type I scientists believe that commercialisation of research is harmful to academic science and they see the growing pressures for applicability in research as a threat to scientific autonomy. In the survey, the majority said that they were not prepared 'to alter their research programmes to accommodate industrial demands', indicating their resistance against industrial encroachment. Three-quarters agreed with the statement that 'engagement in commercial activities has the potential to confuse university's central commitment to knowledge production' (Table 6). This sentiment was also vividly expressed by many of those who wrote their remarks on the questionnaires:

> 'I strongly believe that the commercialisation of research by academia has harmed and has the potential to further harm the role of academia in society…' (Professor, bio-engineering).
>
> 'Universities are selling their souls to the gods of patents and profits' (Lecturer, physics).
>
> '…The notion of universities as institutions where basic research is pursued simply for its own ends is being eroded at an alarming rate. The Age of Enlightenment is becoming an Age of Commercialism and we will all be poorer for it' (Reader, physics).

Type I scientists responded to the rising tide of commercialisation by avoidance or contestation. Some dismissed the environmental changes and others actively contested the legitimacy of these activities. They often evoked the traditional ideals of pure, 'disinterested' research to guard the boundary of basic science. Especially among those who did not see the relevance of industrial engagement, their suspicion of industrial links may well reflect their personal desire to maintain an 'ivory towerish' world of academic science.

> '…I personally am not interested [in industry links]. I can happily get on with my basic research funded principally by biomedical charity' (Professor, biosciences).

> 'Just not very intellectually interested in industry. They evaluate their findings differently. I don't care about money but about intellectual freedom, that is why I am in academia and not in industry!' (Senior lecturer, computer science).

At first sight, it would appear that these Type I traditionalists were using the norms of basic research as a protective resource for self-justification (Mulkay 1976; Waterton 2005). However, there is also ample evidence to suggest that their resistance against commercial endeavours also reflects a genuine concern that private interests may undermine the objectivity of research and pose moral threats to the enterprise of science:

> '…most commercial companies have little interest in research for its own sake, or even sometimes in the truth, they always had to put the bottom line first. This is probably inevitable, but it means that industry support is not in my view a satisfactory way to support academic activity. Findings unhelpful to a commercial company are suppressed, and favourable findings exaggerated.' (Professor, medicine)

> 'Industrial links are not all the same although they are all more or less problematic. For example, links between basic science and the defence industry are entirely morally wrong, links with commercial drug companies are highly problematic, while other links have their own specific associated questions…'(Researcher, mathematics).

The 'boundary work' of Type I scientists seeks to reinforce the institutional logics and integrity of academic science, and maintain their extant role identity. The norms of 'disinterestedness' and 'communalism' were often invoked, in their conversations and written comments, not simply for self-interested protection but also to defend the collective enterprise of academic science against the encroachment of commercial interests.

Type II 'traditional hybrids': boundary testing and maintenance

Scientists belonging to this category share the traditionalists' view that engagement in commercial activities can be harmful to academic science and they also believe in the importance of maintaining a boundary between academia and industry. However,

they adopt a more accommodating attitude and are prepared to test the boundary relationships to explore the emerging opportunities in anticipation of possible benefits. About one-third of those surveyed said they were 'willing to alter their research programmes to accommodate industrial demands' (31% neutral), indicating a more flexible approach (Table 5).

Type II scientists also recognise a need to meet the growing expectations for industrial collaboration. Several of those who had been involved in start-up companies talked about their 'social obligations' as scientists and the 'culture' of their departments:

> '…we felt obliged as one is obliged actually, apart from some arty research, to do your best to commercialise the outfits…From my perspective, I feel starting up starter companies is kind of what you are supposed to do. It's kind of what you should try to do, obviously the government gives you money because it's supposed to help the economy and to do research ultimately it should help the economy. So I thought that's what I am supposed to do' (Professor, biosciences).

> '…it was a directive from above, you know, our Head of Department was very keen that we open up… it was the culture of the department at the time. I mean it certainly wasn't everybody, but there was five… four or five of us getting involved at one level or another. And it was the culture that, you know if you were going to be a top academic, you know, that's one of the things you had to cover…' (Professor, biosciences).

Underlying this apparent institutional compliance was a pragmatic personal adaptive strategy that many of the traditional hybrids pursued in the changing research environment. Many believed that demonstrating an entrepreneurial stance in their work would enhance their chance of obtaining the much needed research funding. One young professor in biophysics, who had been successful in obtaining major funding for his lab in the past few years, described in a somewhat cynical manner how he went about this:

> 'The Government was making it harder and harder to do pure research and so if you could show application in the context of, you know, collaborative work with industry, it was much easier to get funding……
>
> So, for example, I have to write a report for my Wellcome Trust Senior Fellowship, my annual report saying how great I am. And one of the questions there is, you know, what have you done that is impressive outside just running a lab? So you know, I think, oh it would be great if I had some… you know if I showed I'd started a company or …Yeah, so I'm going to bullshit about my contacts with company X and you know, and it's all a case of building that up and that is more impressive than saying, "oh well I gave four lectures and three tutorials''…'.

Despite the cynicism, this professor also stated in the interview that industrial links had indeed become part of his 'academic profile' that contributed to his reputation and probably even career success.

The ‘traditional hybrids’ were individualistic and pragmatic in crafting their own versions of ‘boundary work’. While retaining many of the characteristic traits of the Type I traditionalists, they sought to test the science-business boundary relationships by experimenting with new practices and trying out new roles. Many recognised that commercial engagement had gained increased institutional legitimacy and it was something that might bring academic credentials and benefit their careers. However, such activities also challenged their focal scientific values and they were only too acutely aware that commercial activities had not gained wide acceptance at a deeper cultural-cognitive level among their colleagues. A Type II bioscientist engaged in a start-up company, for example, expressed his concerns about being seen by his colleagues as having ‘crossed over to the dark side’ and the ‘mistake’ that he made in ‘trying to put commercial activities next to the academic ones’. Another mocked his own activities in seeking company funding by repeatedly saying that he was ‘selling his soul…’ and thought those who were too deeply involved in commercial activities were ‘walking a very narrow line’. One professor who had just embarked on a company start-up project was deeply frustrated by the fact that a once prominent ‘scientist-entrepreneur’ in his department left the university because ‘his research had disappeared to zero, and he was full-time talking to business people’. These narratives reveal the scientists’ deep-seated worries about the potential career and identity risks that commercial activities entail.

The position of the traditional hybrids was somewhat indeterminate and ambiguous. Kosmala and Herrbash (2006:1399) argue that ambivalence is a strategy of self-protection – it enables individuals to distance themselves from external control, and to create a ‘free space’ for autonomy. The Type II scientists sought to experiment with new work practices without undermining the established scientific norms and their dominant academic role identity. This ambivalence allows them to create ‘provisional selves’ (Ibarra 1999:765) as temporary solutions to experiment with new roles.

One might even say that these scientists were ‘hedging their bets’ and they would change directions based on evaluations of the success or failures of the trial efforts. The accounts of the interviews and written comments on the questionnaires show the scientists’ meticulous assessment of their experiences. Many of these served as warnings about the risks of over-stepping the science-business boundaries:

> ‘Research donations (unencumbered, charitable) from industry are now our preferred option since any explicit "research contract" outlining collaborative or contractual research with funding from industry nowadays brings massive and ill-conceived IP terms and conditions…’ (Senior lecturer, computer science).

> ‘In retrospect, the time I spent on commercial links with industry distracted my concentration on research objectives, and my career might have had more fundamental impact if I had pursued those research objectives single-mindedly’ (Professor, biosciences).

Several of the traditional hybrids told negative stories of their own or their colleagues’ ‘failures’ in company ventures. They talked about how their own attitudes and the ‘culture’ of their Departments had shifted from away from the ‘entrepreneurial’ pull towards more a basic research orientation as a result of the unsuccessful ventures:

> '… it [company start-up] was a great, a very good experience and because you learn… if nothing else, whether you like to do it or not and I think that for what you get out of it, I'm pleased that I learnt that it's not a good thing' (Professor, biophysics).

> 'I now think that the chances of such ventures being successful are so remote – this weakens the argument that academic researchers should strongly pursue such avenues for the benefit of the HEI. I believe that there is now a general refocusing of effort towards more purely academic pursuits, at least in our Department' (Professor, biochemistry).

The boundary work of the traditional hybrids is both individually self-serving and organisationally significant in creating opportunities for testing new behaviour. It creates a free space for navigating a transition and experiencing alternative perspectives without posing a major threat to the established norms. Type II scientists seek to 'test' as well as 'maintain' the science and business boundary.

Type III 'entrepreneurial hybrids': boundary negotiation and expansion

Type III scientists are also hybrids in that they combine a new school entrepreneurial orientation with an old school commitment to the core values and norms of academic science. For these scientists, the boundary between university and industry is permeable and provides an open space within which knowledge production and application can be effectively combined. They emphasised an interactive relationship between basic and applied research, and appeared to be comfortable and confident in crossing the science-business boundary. Relative to their traditionally-oriented colleagues, a much smaller proportion of the Type III scientists surveyed agreed that 'engagement in commercial activities has the potential to confuse university's central commitment to knowledge production'. Conversely, a higher proportion said that they were 'willing to alter their research programmes to accommodate industrial demands' (Table 5). The majority believed in the positive benefits of industrial engagement:

> 'Industrial links have been very important with respect to gifts of reagents without which many of my basic scientific research questions could not be addressed' (Reader; medicine)

> 'The consultancy work is invaluable in turning up ideas for research' (Professor, Chemical engineering).

These scientists are experienced and strategic in the way they interface with industry. They will attempt to influence or manipulate the expectations of their industrial partners in order to shape the relationships. As one scientist put it: 'we have very clear ideas of what we want to do and we'll play the company's [game]… you know, we're not going to be pushed around.' For these scientists, the boundary between academia and industry provides an overlapping space where bargaining and negotiation takes place. While recognising the benefits of industrial ties, the entrepreneurial hybrids are also aware of their pitfalls and potential risks. They would seek to protect the hard core of scientific values when they felt that industry had overreached: 'science must come first, no compromise' (interview with a professor). The problems of 'publication restriction', 'control over intellectual property rights'

> ‘What you need is clear contracts with industry so that if there are people, you know who are doing PhD’s or who are doing basic research, you have to have clear clauses to say that, you know… the company for example should be given the results freely but there should be no embargo on publication.. the ownership comes into it as well, you know who actually owns the IP and so that needs to be very carefully sorted out before you start, you know who owns what’ (Professor, biosciences).

> ‘One of the things I tried to make sure always happens if I work with a company is that I publish. I am not particularly interested in making a lot of money from patents or anything like that I would like the work to be published and disseminated… And so you see if I publish then all the vendors can make products from my ideas. If I patent and license to just one then you know you are very reliant on that vendor then because you know they may decide after a little while ‘no’, they don’t want to make the product and then it dies’ (Professor, system engineering)

Some scientists would use their specialist expertise and personal scientific eminence to exert control over their industrial partners. One bioscience professor, for example, used non-exclusive licensing deals with companies to ensure that no one single company could have complete control over his work:

> ‘..when I published a paper on X, which is an enzyme involved in high blood pressure and I suggested this might be used to design anti-hypertensives and a lot of companies wrote to me and so I made a deal with thirty companies…
> I sold them the same thing. Polygamy works very well. If you are monogamous in your relationship with a large company then you become completely ruled by your partner. If you have a lot of partners you become very powerful and more effective… I licensed to a lot… ‘ *(Laughing).*

Unlike the Type II traditional hybrids, the Type III scientists did not appear to experience cognitive dissonance or role identity tension when they embarked on commercial ventures. They perceived such endeavours as largely legitimate and would use ‘old’ academic frames to interpret the meaning of commercial engagement to resolve any normative tension. For many of the entrepreneurial hybrids, knowledge application and commercialisation amounts to an extension of their scientific role following long years of fundamental research. The following remark is indicative:

> ‘…you know, typically speaking, the ability to commercialise comes from years probably of fundamental research, which informs the company and what is feasible, so it’s not a magic invention in our world, you know, it’s not suddenly invented something that no one had every dreamt of and it’s immediately profitable, it’s a slow and one might say, laborious process

> basically… I still, perhaps it's too nostalgic, but I like to think our jobs are a mixture of that degree of freedom to operate and to push the boundaries, that may well lead… that boundary may well lead to some commercial thing or a licensing or a spin out…' (Professor, biosciences).

For some, forming a spin-off company was a way of asserting control over the knowledge exploitation process so as to exclude unwanted commercial interests from big companies: '...but I suspect at the end of the day, you know to get sort of independence and to be able to do things beyond a certain level, I suspect you really need to have a company …' (Professor, biosciences; company founder).

Like Type II traditional hybrids, Type III scientists also frequently mentioned how they used industrial links to generate the much needed financial resources for their laboratories (see also, Table 4). The 'resource frame' for some of the entrepreneurial hybrids includes also personal income. This money incentive, however, is not supposed to be a legitimate one for 'truthful' scientists engaging in 'disinterested' research. The scientists reframed what this meant for them to justify their involvement in 'profit making' activities which appear to be at odds with their socialised academic identity. For example, some talked about their 'freedom' and 'right' to engage in such activities to compensate for their low pay:

> '…I think I'm being underpaid and so I've always campaigned for better salaries in the university world but I've also always championed the rights that if we're going to be paid very little we should be able to write books or do consultancies or form companies' (Professor, biosciences).

Beyond this nuanced 'self-interested' economic narrative, the majority of the entrepreneurial hybrids interviewed stressed the wider societal benefits of their commercial ventures. The following comment is illustrative:

> '… even if I get no drugs in the end and we still have a good chance, I've put a lot of money into the local economy, I've given jobs and what I'm absolutely convinced is that the method we've developed is going to be useful in making drugs in the comings years… I think that we as academics have a responsibility, especially in University X, to the nation really, we're in a very privileged position…And our money comes from the State or from charities' (Professor, biosciences).

The entrepreneurial hybrids have been able to expand the boundaries of their work role to incorporate commercial practices without sacrificing their focal academic identity. The majority interviewed saw themselves as 'a scientist first and foremost'. They believed that their commitment to academic values, clear research agenda and scientific reputation had enabled them to reap the benefits of commercial endeavours without the attendant negative implications. A professor who had been actively engaged in commercial activities described his scientific reputation as 'a central core' that gave him the freedom to do many other things outside academia: '…my first priority is to be a world leader in my research myself… the only defence of somebody like myself is to do better than anyone else in my academic job…'. These scientists are similar to what Zucker et al (2002) describe as 'star scientists' who pursue dual knowledge production while remaining firmly rooted in the academic community.

They pursue commercialisation of research but not all its attendant commercial implications. They actively seek to determine the shape and content of their enterprise activities so as to maintain their scientific autonomy.

At the socio-cognitive level, Type III scientists use 'mediating beliefs' (Pratt and Foreman 2000:33) to reconcile the internal inconsistencies associated with their simultaneous partake in science and business. Patenting and company formation, for example, are not seen as vehicles for profit making but as mechanisms that enable them to have control over knowledge exploitation and thus to protect the integrity of science. At the more practical level, they are meticulous in creating clarity and social order across the academic-commercial boundary in their daily work. They would ensure that the two domains were kept separate in their laboratories to avoid conflict of interest:

> 'I mean the ideas that we [the company] have are a sort of specific area of what I'm doing in my lab but what I'm doing in my laboratory is, until recently, absolutely fundamental descriptive work funded by Cancer Research UK and by Wellcome Trust and I had to be careful not to get into a conflicted state, so I kept that separate…I kept the topics distinct and I kept the equipment distinct, I duplicated things if necessary. I had a yellow line down the middle of the lab, you couldn't see it but nothing crossed it' (Professor, biochemistry).

> 'It was very important we weren't too involved with the company. That there was a big wall between Company X [a spin-off] and our [research] group. Because otherwise you know the Wellcome Trust would have been in trouble because it could have been seen that their money was helping the company and their charitable status would have been in trouble. So we had to be completely distinct from Company X' (Professor, pharmacology).

The boundary work of Type III entrepreneurial hybrids is complex and clever. These scientists actively negotiate the boundaries between science and business, and seek to map out new social spaces for their work while protecting their autonomy and role identity. The way they negotiate the blurred boundaries between the two arenas often involves an apparent paradoxical combinations of contradictory institutional logics and perspectives. Yet, these scientists are adept at resolving normative tension and avoiding conflict of interest. Henkel (2005:173) argues that scientists in the contemporary environment 'must negotiate between social and institutional pressures and preservation of identity'. The boundary work of the entrepreneurial hybrids does precisely this.

Type IV 'entrepreneurial scientists': boundary inclusion and fusion

Type IV 'entrepreneurial scientists' see the boundary between academia and industry as entirely permeable and flexible, and use it as a basis for bridging and inclusion. Like their Type III counterparts, Type IV scientists are also experienced participants in university-industry links. However, they have gone further down the 'entrepreneurial path', with a conviction to linking knowledge production more tightly to its practical use and commercial exploitation. The dominant majority surveyed said

they were 'willing to alter their research programmes to accommodate industrial demands' (see, Table 5).

To the entrepreneurial scientists, science is inherently commercial and the pursuit of commercial science is entirely logical and compatible with their academic role. The traditional ideal of 'disinterested science' seems to bear little significance to the way these scientists approach their research. A Type IV professor in physics, for example, talked about the 'need to be aware of [commercial] opportunities and the need to spot them', and the importance of 'having a perspective on how commercialisation of fundamental research works' so that 'you're not working in areas of science that has absolutely no chance of being kind of exploitable'. Those in the more applied disciplines believed that the worlds of science and commerce were completely merged and it would be difficult to draw a clear boundary between the two: 'The world is more industrial…to talk about science as separate from marketing aims of big corporations is naïve' (interview with a biomedical professor). To these entrepreneurial scientists, the Mertonian ideal of academic science was no more than an imaginary mythical world that only existed for those who believe in '… some Victorian nirvana of ivory towers doing wonderful intellectual research', in the words of a Type IV professor interviewed.

Scientists holding a Type IV orientation are ardent advocates of Burton Clark's (1998) notion of the 'entrepreneurial university' in that they believe in the critical importance for universities and academics to participate in the market and maximise opportunities for commercialisation in order to achieve financial self-reliance. The following remarks by a Type IV professor in bio-medicine sum up this view well:

> '… well the key thing that my message to you is that Universities will not be successful until we understand the value of intellectual property in University and how to exploit that. The Universities in the UK need one thousand Company X (a spin-off) if we're going to have real funding of the University independent of the Government, I believe in that very much...
>
> '…every Post Doc and every Professor should know what a patent is … Yes as I said to you we need a thousand Company X and that would be possible. This University could produce fifty Company X'.

In contrast to their traditionally-oriented colleagues who often use the ideal of 'disinterested research' to protect and defend the boundary of academic science, Type IV scientists do precisely the opposite. They develop their own distinctive version of boundary work to challenge the institutional rules and values of academic science. They do so by mocking and belittling the role and contribution of basic research as opposed to applied research. One Type IV professor in computer science, for example, pointed out that the 'theoreticians' in his department were 'at least twenty years behind' and that they would need to justify their existence in relation to those who were engaged in applied work. For the most entrepreneurial new school scientists, research without practical relevance or that bears no technological fruits is less valuable.

The boundary work of the entrepreneurial scientists also challenges the norm of communism that gives priority to publication over patenting. To these scientists,

patents not only constitute an alternative source of scientific credit but they are also an important economic resource that must be exploited:

> '… it's [patents] important as part of assessing the impact of someone's research you know, if it's good enough to do a thriving patent…it means you've been concentrating hard enough, they're asking you important questions..So when I'm thinking about a research project, I'm definitely always thinking about the intellectual property…' (Professor, medicine)

> '..if you discover something then I believe you should patent it immediately if you want to patent it which is very cheap and then publish…and also those who say we need open, free dissemination of science, what we need as well is for that science to have an effect on society and the effect on society… we're not a communist state, is via patents and via using the tool of capitalism, so there are several reasons why we should patent and I do not believe that patenting and free dissemination are in conflict' (Professor, biomedicine).

At a practical level, the entrepreneurial scientists sought to incorporate their mode of operation into the established academic structure. One professor in computing science talked about how he would 'cheat in every way possible in the system to bring applied people in and make their lives possible' in the department. Another in biosciences actively championed and developed what he described as an 'ideal organizational structure' to 'allow the companies to do their research within the university labs'. Unlike the Type III entrepreneurial hybrids who often draw a clear line between their academic and commercial activities to avoid conflict of interest, the Type IV scientists seek to integrate the two into a single structure.

For these scientists, deep engagement with industry constitutes part of their established work routines and role identities. For example, one Type IV scientist interviewed described 'entrepreneurial engagement' as part of 'the repertoire, base skills' that he should retain as a professional scientist. Others saw their parallel activities in the academic and commercial arenas as an integral part of their work roles: '…it's part of my life, you know, it's not dislocated particularly'. Another Type IV professor pointed out in the interview that technology transfer in his case was his 'academic self' talking to his 'industrial self': 'It all happens together… that's the heart of how it works, no barriers right. You can do the same thing at once…'. This 'talking to himself perspective' reflects the fusion of two different role identities into a hybrid, two-faced one.

While Type III scientists use various legitimating themes and mediating beliefs to accommodate commercial science within their academic frames, Type IV scientists assert the rationality and righteousness of their entrepreneurial convictions. Some openly acknowledged the importance of personal financial gains (see also, Table 5). The following remarks made by two company founders are illustrative:

> '…you've got to make money, the company is to make money, right, it's not like another item on your frigging CV, it's to make money! That's why you do it! It's not a CV driven thing, it's not like a publication…' (Professor, computer science)

> Money. Money, money, money. It is just money. I mean if you think about academic jobs whether perfectly reasonably paid… You are never going to earn the same thing as a banker or you know a lawyer or something. So I think if you can incentivize people – even with a few thousand pounds actually, you know, it is quite helpful' (Professor, biosciences).

It would appear that commercial practices have achieved a deep cultural cognitive legitimacy among the Type IV scientists. However, probing deeper into their work experiences and role identities reveals a much more ambiguous and tension-prone picture. Several of the Type IV scientists interviewed complained about how the 'old norms' and the 'real culture' continued to erect barriers to their boundary bridging activities, and that they would have to 'push back on that' and 'work very hard to manage the considerable suspicion' from their colleagues. Another pointed out that there was 'an institutionalised negativity' towards entrepreneurial activities because they were not seen as 'high grade' and the view that 'industrial stuff is not nice' still 'permeate the entire system'. Besides the subtle cultural sanction, the Type IV scientists were particularly adamant that the system continued to reward predominately scientific achievements in the form of publications and peer recognition, and downplayed their contributions to knowledge exploitation. For the scientists who simultaneously commit themselves to academic and commercial science, a successful career would imply performing well in their dual roles across the science and business realms, and meeting the goals and performance criteria of the two very different systems. As one Type IV scientist put it:

> 'I want to be judged on a completely level playing field with other academics who are not exposed to the benefits and disadvantages of all these other bells and whistles that I've chosen to create around the periphery, you know I have to win, you know and be competitive with my colleagues who don't do this… I have to be in both camps as well as the middle all at the same time if you see what I mean, I am trying to be both a fully functional academic and an entrepreneur functioning in these companies and somebody who's also bridging these roles all at the same time, so I've maybe made it more difficult for myself…' (Senior researcher, biosciences)

The majority of the Type IV scientists interviewed felt that their decision to go down the entrepreneurial path was a 'risky' endeavour because it could jeopardise their academic careers. Those who were professors described themselves as being 'lucky' and 'managed to get away with it'. For those who had not yet made it to the top of the career hierarchy, the career risk was genuine and there was a constant fear of being de-coupled from the core academic system. One young bio-scientist, who had founded a company, described his position as being like 'a waiter with all those plates' and feared that the 'whole thing could collapse' around him any time. Another who is a Reader in physics, also a company founder, had experienced such difficulties in balancing his dual role that he was making a genuine assessment about whether to remain full time in academia: 'I think I have had to make a careful and studied decision that I want to go down this road in the knowledge that it is almost certainly preventing my promotion within the university…'.

Even among the apparently successful entrepreneurial professors, the narratives in the interviews reveal a sense of anxiety in keeping up their academic performance. One

professor thought his publication track record was ‘a bit thin’ for a professor in a top research university of his, and mentioned several times in the interview that he was ‘no 400 paper journal man’ compared with one of his more eminent colleagues. Another talked about his role conflict in satisfying the different responsibilities and not having time for his own research: ‘I have nightmares about the volume of work I have to deal with… I genuinely wake up sweating in the middle of the night… these [industrial] activities take time and they take time away from other things and if you value them more highly you spend more time on them, and the time that’s spent on them is time away from teaching, time away from you know, fundamental research and theoretical speculation, time away from scholarship…’. Conflict of commitment and role overload appear to be a widespread problem experienced by the Type IV entrepreneurial scientists.

The boundary work undertaken by Type IV scientists is contentious and tension-prone. They attack and dismiss the traditional model of academic science which remains as the default ideal for many. This inevitably breeds tension and risks jeopardizing their acceptance by academic colleagues. The tension inherent in the boundary work of Type IV scientists is also manifest at the individual level in the role identity conflict experienced. For the individual scientists, the decision to pursue commercial activities is akin to managing multiple role identities which can lead to role identity overload and conflict (George et al 2005). Individuals may adopt different strategies to resolve the conflict. Type III scientists resolve the tension by maintaining one dominant academic identity and creating mediating beliefs to reconcile the internal inconsistencies. Type IV scientists, by contrast, seek to fuse the academic role with the entrepreneurial one to make a two-faced hybrid identity. However, the hybrid identity maintains distinct elements from the pre-existing identities, and thus role tension may occur when any elements from the original identities come into conflict (Pratt and Foreman 2000: 31-2). The transition from the role of a scientist to that of an entrepreneur, even in the case of the most entrepreneurial Type IV scientists, appears to be partial and fraught with inner tension. This is not only because the gap to be bridged between the identities is considerable, but also forgoing the focal academic identity would mean threatening the very professional self and scientific esteem upon which the entrepreneurial one is built.

DISCUSSION

The increased penetration of the marketplace into the institutional fabric of universities has generated much debate and uncertainty about the shifting nature of academic scientific work. Proponents of academic entrepreneurialism stress the growing prominence of the new school entrepreneurial scientists. Critics, by contrast, paint a dark world of academic capitalism where the norms and values of academic science are gradually being eroded, and the position of traditional scientists is under threat. The analysis presented in this paper does not lend support to either view. The emerging picture is far more complex and fluid than is presented in these generalized observations.

The typology of scientists based on a continuum defined by two polar sets of values, the ‘traditional’ vs. ‘entrepreneurial’, has provided a useful framework for examining the emerging patterns of conflict and agreement in scientists’ responses to the

changing environment. It avoids the limitations of a dichotomous view which projects a clear divide between the 'old' Mertonian values of basic science and 'new' values of entrepreneurialism, assuming a linear process of change with the new displacing the old. It is important to note that both traditional and entrepreneurial types of academics have always existed in universities, but changes in social conditions may determine which type becomes more dominant and which set of values gains greater legitimacy at any given time. As Hacket (2001: 203) notes, 'historical events that disturb society do not create new values and ethics out of whole cloth, nor do they necessarily pose novel value conflicts, but instead they alter the balance between pre-existing polar opposites'. The two polar positions, I and IV, represent two gravitational fields or latent pairs of principles in academic science which are always in tension. Recent changes in science-business relationships appear to have altered the balance, giving the entrepreneurial type a greater degree of socio-political legitimacy than before. The hybrids, Types II and III, denote the sociological ambivalence of scientists and their attempts to bridge across contradictory positions. Treating hybrids as distinctive types enables us to explore the potential for strategic action and change at the intersection of different institutional spheres.

All the scientists studied have a clear sense of shifting boundaries but they diverge in their adaptive strategies. Type I traditional scientists see the demands of industrial application as constraints to their work and an assault on their professional autonomy. The boundary work of these scientists seeks to maintain the traditional ideals of basic science and protect their academic role identity. Although these scientists may be increasingly constrained by their continued reliance on diminishing public funding, they remain a powerful force especially in the disciplines characterised by a strong basic research orientation. Their determined opposition to the rising tide of commercialisation restrains the move towards entrepreneurialism and keeps the controversy and debate alive. In contrast, Type IV entrepreneurial scientists perceive increased commercialisation as an opportunity to establish an alternative mode of knowledge production. This category may well be gaining greater prominence in the fields with growing market opportunities for research commercialisation. Their attempt to fuse the science-business boundaries and assimilate a strong commercial perspective, however, breeds tension and risks jeopardizing their acceptance by academic colleagues. Type IV scientists comprise a relative small share of the survey sample (11%) and their actual presence in the academic population may well be less significant. Their 'boundary work' may not constitute what Gieryn (1983: 789) refers to as an 'effective ideological style' that could establish entrepreneurial science as a hegemonic model in academia.

The hybrids, Types II and III, comprise the great majority and have been particularly adept at mapping out their own social spaces for navigating a transition. Although the two categories differ in the strength of their gravitation towards entrepreneurialism, they both seek to exploit and manipulate the changing circumstances to their advantage. Oliver (1991) argues that manipulation is the most active response to institutional pressures because actors actively seek to influence, change or co-opt institutional expectations and evaluations. Type II traditional hybrids use the social space at the intersection of science and business for experimentation. Their fluid position enables them incrementally to move towards entrepreneurialism or retreat into the bounded academic arena, depending on changing circumstances or the outcome of their trail- and-error efforts. This indeterminate position may cause

cognitive dissonance and psychological discomfort, but it also creates opportunities for evaluation, learning and making sense of the new possibilities (Piderit 2000). Moreover, it allows them to 'float' at the intersection of different institutional domains, change direction or define a new hybrid domain by mixing elements of the intersecting institutions (Delmestri 2006; Smith-Doerr 2005).

Type III entrepreneurial hybrids are those who have developed a distinctive negotiation zone at the interface between academia and industry. They vigorously seek to mobilise material and knowledge resources across the two arenas to support and expand their research. These scientists have acquired substantial entrepreneurial knowledge through work experience and are particularly skilled at controlling the research agendas in both worlds. This is the category of scientists most likely to report positive influence of industrial links on their research and careers (see, Table 5). While looking towards the industrial world and selectively crossing the boundaries, their values and role identity are firmly embedded in the academic community. The ambivalence of these scientists lies in their apparently paradoxical combination of the logics of science and business in their work, and their use of seemingly conflicting frames to legitimate their boundary crossing activities. However, Type III scientists do not appear to experience psychological discomfort despite their structurally ambivalent position. They actively negotiate their roles and seek to co-opt business practices into their repertoire of behaviour, but on their own terms. These tactics neutralize opposition and enhance the legitimacy of their commercial ventures in the academic arena. At the individual cognitive level, they resolve role identity conflict by altering the meaning of commercial practices to better fit with the logic of academic science.

It is clear that scientists do not respond uniformly to the changing institutional environment. There is evidence of open or subtle resistance against the encroachment of a commercial ethos, but also obvious attempts to bridge the contradictory demands of science and business, whether reluctant or positive. Such sociological ambivalence, arguably, is a character of science and scientists have always had to defend their position in response to external challenges. The increasingly blurred boundary between university and industry, and growing pressure on scientists to exploit the commercial opportunities in an expanding array of scientific fields have brought the ambivalence of scientists to the forefront. Gieryn (1999) argues that boundary work is most apparent in situations in which boundaries are contested. The scientists looked at in this study are engaging in collective professional boundary work as well as personal boundary work (Waterton 2005) as they seek to defend and establish the value of their work in the shifting terrain of academic science. Collectively, scientists are engaging in what Friedson (1994) referred to as the 'maintenance project', searching for a coherent professional identity as they increasingly operate within open and contested terrains. At the individual level, they are crafting their own versions of boundary work to map out social spaces for pursuing their professional and career goals.

Amidst the apparent ambivalence and diversity, the majority of the scientists engaged in industrial links, notably types III and IV, perceived a positive impact of industrial links on their research and careers (see, Table 5). This indicates that they have been able to assert a sufficient degree of control over the science-business relationship to pursue their own objectives. The analysis also reveals strong continuity and stability

in the role identity of the majority of the scientists. While it is possible for individuals to hold multiple identities salient to various roles and contexts (Kreiner, et al. 2006), some aspects of individuals' identity are 'central' and often remain salient and can be held strongly even in the face of external challenges (Markus and Kunda 1986). For the majority of academic scientists, their role identity is deeply rooted in a strong scientific ethos that cherishes autonomy and dedication to knowledge. This focal identity is also the result of long years of graduate training and socialisation, and is intimately tied to an institutionalised career reward system based on scientific credibility and peer status and it differs substantially from an entrepreneurial one associated with commercial science. The boundary between science and business is becoming fuzzy, but not dissolved. It continues to have great symbolic significance for the majority of scientists and serves to underpin their role identity.

This continuity has enabled scientists to adapt to the external challenges without undermining the core logic of academic science. It has to be remembered that one of the unique features of universities is the strong influence of academics on defining their missions and goals, and the management of daily routines of work. Radical transformation in academic science is unlikely to take place without widespread acceptance of commercial practices among the majority of scientists at the deeper socio-cognitive level. This does not appear to have occurred. The findings of this study are consistent with the results of several other studies (Enders 1999; George, et al. 2005; Henkel 2005) which also show a strong continuity in the professional role identity of academic scientists, despite challenges from the environment. Even in the US where the institutional framework for promoting academic entrepreneurialism is much more developed than in the UK, empirical evidence on the effects of these changes on the norms and practices of academic scientific work suggests a picture that is largely mixed and riddled with inconsistencies and anomalies (Owen-Smith and Powell 2001; Vallas and Lee Kleinman 2008; Welsh, et al. 2008).

CONCLUSION

The remaking of boundaries between science and business is a contentious and contested process. Science itself is a diverse activity full of anomaly and paradox, and managing ambivalence is part of the daily routine of scientific work which also shapes the social structure that produces it. Neo-institutional theory highlights the agency role of actors in shaping the change and reproduction of institutions. It postulates that actions can either maintain or transform existing institutional structures. This study has demonstrated the capacity of scientists to defend and negotiate their positions, and to exercise agency through boundary work.

Those who see the growing power of the marketplace and the ethos of commercial science capturing and corrupting the cognitive norms of scientists will need to take account of how actors can resist change and alter the meanings of new practices to fit with their 'old' norms (McLoughlin, et al. 2005; Murray 2006). Authors who predict a shift in the work orientations of scientists towards the 'new' entrepreneurial mode should bear in mind that this can occur within a strong continuity of the 'old' academic frame as actors mix disparate logics at the blurred boundaries between institutional sectors. DiMaggio (1997:268) argues that individuals are capable of maintaining inconsistent action frames which can be invoked in particular situational contexts. Hybrids in boundary-spanning positions can bridge contradictory logics and

act as powerful agents of change. However, it should be noted that the move from the 'traditional' to the 'entrepreneurial' mode is not necessarily a linear process as it can be halted, or even reverted, as a result of actor learning or contestation. As Coyvas and Powell note (2006:346), social life is full of situations of partial institutionalisation in which new practices or values can prompt resistance from incumbents.

This study highlights the contribution of a micro-level perspective to understand the responses of scientists to the shifting environment. The focus on individual experience does not preclude the influence of the scientific fields or institutions to which they are affiliated on their orientations. Previous research (e.g. Kenney and Goe 2004) has shown that the cultural norms of departments and policies of universities can influence scientists' entrepreneurial engagements. While a systematic analysis of these factors is beyond the scope of this study, a fruitful line for future enquiry would be to explore how individual orientations can be mediated by the disciplinary or institutional contexts. This study has looked at the experiences of 'elite scientists' in major research universities who have relatively strong bargaining power and varied resource options to exert control over the environment. The situation may be more constraining for scientists in smaller or newer universities with less reputational and institutional resources to defend their positions. Future research could be extended to include different types of institutions to explore the potentially divergent experiences of a wider population of academics, and the relevance of the typology developed in this study.

Table 1 The interview and survey samples by discipline

Discipline	No of interviewees	No. of survey responses and response rate (%)
Biosciences/medicine	13	346 (21%)*
Physical sciences	12	213 (25%)
Computer science/engineering	11	174 (26%)
Total	36	733 (24%)

* The slightly lower response rate in biosciences/medicine could be due to the fact that the mailing lists obtained from the medical departments included certain number of clinical staff who should not have been included in the target population.

Table 2 A typology of scientists' orientations towards university-industry ties

	Beliefs about academia and industry boundary	**Extent and modes of engagement with industry**	**Main motivating factors**	**Perceived legitimacy of knowledge commercialisation**	**Boundary work strategies and role identities**
Type I 'Traditional'	- believes academia and industry should be distinct and pursue success strictly in academic arena	-some collaborative links but of an intermittent nature	-Mainly to obtain funding and resources for research	Resistance -seen as an assault on academic ethos and professional autonomy	-Boundary separation and expulsion -Retain extant academic role identity
Type II 'Traditional hybrid'	- believes academia and industry should be distinct, but also recognises importance of science-business collaboration	-mainly collaborative links with intermittent involvement in some commercial activities	-Funding and resources for research most important amongst other factors	Accommodation -not necessarily desirable but an inevitable development -pragmatic and obligational	-Boundary testing and maintenance -Retain and protect dominant role identity as academic scientist
Type III 'Entrepreneurial hybrid'	-believes in the fundamental importance of science-business collaboration but recognises the need to maintain academia and industry boundary	- continuous engagement in a wide range of collaborative and commercial activities	-Funding and resources for research most important -Application/exploitation of research, knowledge exchange and professional networking also important	Incorporation and co-optation -adopt commercial practices but not necessarily all its attendant commercial meanings	-Boundary negotiation and expansion -Hybrid roles but retain strong focal academic identity
Type IV 'Entrepreneurial'	-believes in the fundamental importance of science-business collaboration	-continuous engagement in a wide range of collaborative and commercial activities -strong commercial ties with firms	-Application/exploitation of research most important -Funding and resources for research, knowledge exchange and professional networking also important -personal pecuniary gains also relevant	Acceptance and veneration -commercial practices embedded in work routines	-Boundary inclusion and fusion -Fuse dual role identities to make a two-faced identity

Table 3 Distribution of the interview and survey samples by type and engagement in industrial links

Typology	**Interview sample***	**Survey sample**	**Engagement in industrial links (Survey respondents)**		
			None	Collaborative**	Commercial***
Type I. Traditional	3 (8%)	108 (17%)	57%	30%	13%
Type II. Traditional hybrid	8 (22%)	215 (33%)	21%	48%	31%
Type III. Entrepreneurial hybrid	16 (44%)	251 (39%)	14%	44%	42%
Type IV Entrepreneurial	9 (25%)	69 (11%)	15%	26%	59%
Total No. of survey respondents/interviewees (N)	36 (100%)	643 (100%)	24%	41%	35%

*All the interviewees were engaged in industrial links: 22 collaborative and 14 commercial.
**Collaborative links: including collaborative research, contract research, consultancy, student sponsorship and joint publication.
***Commercial links: including patenting, licensing, affiliation with start-ups and company formation.

Table 4 Factors motivating industrial links

Q. *Which of the following factors have motivated you personally to engage in industrial links activities?*
(Multiple answers)

% selected the '*important*' and '*very important*' replies

Motivating factors*	**Type I**	**Type II**	**Type III**	**Type IV**	**All types combined**
To increase funding and other research resources	55%	85%	90%	71%	82%
Application & exploitation of research results	32	56	82	84	68
To create opportunities for Knowledge exchange/transfer	40	50	78	73	65
To build personal and professional networks	35	48	68	64	57
To enhance the visibility of your research	26	38	61	50	46
To increase your personal income	14	20	27	51	26

* Variation between types significant $p<0.001$
N=510 (Total no. of those with industrial links responding to the question)

Table 5 Evaluation of industrial ties and perceived influence on research and careers

% agree/agree strongly
% disagree/disagree strongly

	Type I	Type II	Type III	Type IV
Engagement in commercial activities has the potential to confuse university's central commitment to knowledge production (N=637)	**74** *12*	**66** *14*	**48** *33*	**38** *39*
I am willing to alter my research programme to accommodate industrial demands (N=475)*	**16** *60*	**29** *39*	**38** *27*	**60** *18*
Industrial links have stimulated me to develop new areas of research (N=475)*	**16** *53*	**43** *15*	**73** *9*	**65** 19
Have positively influenced my academic career and scientific reputation (N=475)*	**22** *54*	**30** *27*	**60** *12*	**54** *26*

Variation between types significant $p<0.001$
% of 'neutral' replies not shown
*****Only those with industrial links were asked to respond to these questions.

Appendix A

Survey question used to categorise orientations of scientists

Please indicate which of the following statements best describe your professional orientation (indicate your first best and second best choice if appropriate)

	First best	Second best
1. I believe that academia and industry should be distinct and I pursue success strictly in the academic arena	( )	( )
2. I believe that academia and industry should be distinct but I pursue industrial links activities mainly to acquire resources to support academic research	( )	( )
3. I believe in the fundamental importance of academic-industry collaboration and I pursue industrial links activities for scientific advancement	( )	( )
4. I believe in the fundamental importance of academic-industry collaboration and I pursue industrial links activities for application and commercial exploitation	( )	( )

Table A Typology of scientists' orientations: distribution of responses by first and second best choices*

Typology	**First\second choice**	**1**	**2**	**3**	**4**	**Total (first choice)**
I. Traditional scientists	**1**	26**	57	16	6	**105 (17%)**
II. Traditional hybrids	**2**	48	34**	111	21	**214 (34%)**
III. Entrepreneurial hybrids	**3**	5	100	35**	103	**243 (39%)**
IV. Entrepreneurial scientists	**4**	2	7	49	9**	**67 (11%)**
Total (second choice)		81 (13%)	198 (31%)	211 (34%)	139 (22%)	**627 (100%)**

*The following categories are excluded from the analysis (N=734):
a)No answer to first choice: 56 cases (7.6%)
b)Multiple answers to first choice: 34 cases (4.6%) and second choice: 14 cases (2%)
** No answer to second choice is treated as if the second choice is the same as first choice

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