What motivates academic scientists to engage in research commercialization: 'gold', 'ribbon' or 'puzzle'?

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What Motivates Academic Scientists to Engage in Research Commercialization: ‘Gold’, ‘Ribbon’ or ‘Puzzle’?

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ABSTRACT

This paper employs the three concepts of ‘gold’ (financial rewards), ‘ribbon’ (reputational/career rewards) and ‘puzzle’ (intrinsic satisfaction) to examine the extrinsic and intrinsic aspects of scientists’ motivation for pursuing commercial activities. The study is based on 36 individual interviews and an on-line questionnaire survey of 735 scientists from five major UK research universities. It finds that there is a diversity of motivations for commercial engagement, and that many do so for reputational and intrinsic reasons and that financial rewards play a relatively small part. The paper draws on self-determination theory in social psychology to analyse the relationship between scientists’ value orientations with regard to commercial engagement and their personal motivations. It finds that those with traditional beliefs about the separation of science from commerce are more likely to be extrinsically motivated, using commercialization as a means to obtain resources to support their quest for the ‘ribbon’. In contrast, those identify closely with entrepreneurial norms are intrinsically motivated by the autonomy and ‘puzzle-solving’ involved in applied commercial research while also motivated by the ‘gold’. The study highlights the primacy of scientists’ self motivation, and suggests that a fuller explanation of their commercial behaviour will need to consider a broader mix of motives to include the social and affective aspects of intrinsic motivation. In conclusion, the paper argues that policy to encourage commercial engagement should build on reputational and intrinsic rather than purely financial motivations.

Keywords:
Academic scientists; entrepreneurial university; motivation; scientific norms and values; self-determination theory; research commercialization; knowledge transfer

What motivates academic scientists to engage in research commercialization: ‘gold’, ‘ribbon’ or ‘puzzle’?

1. INTRODUCTION

Growing intensity of university-industry ties and academic research commercialization have generated an intense debate about changing work norms among university scientists (Owen-Smith and Powell, 2001a; Vallas and Lee Kleinman, 2008). Central to this is a growing concern about academics being captured by the ethos of commercialism as they engage in for-profit science. Critics of the entrepreneurial paradigm see academics as ‘promoters as well as victims’ of commercialization (Jacob, 2003) who internalise the ‘intrinsic value of money’ under the academic capitalist knowledge regime (Slaughter, 2001; Slaughter and Rhoades, 2004). Proponents of the entrepreneurial university (Clark, 1998; Etzkowitz, 1998) also underline the for-profit motive in their analysis of the ‘new school’ entrepreneurial scientist. While there is ample evidence of increased academic engagement in commercial activities such as patenting and spin-off company formation (D'Este and Patel, 2007; Siegel et al., 2007), what remains unexplored is whether this reflects the growth of a uniform category of entrepreneurial scientists driven by a common motive. This paper examines the diversity of scientists’ personal motivations for pursuing commercial activities and how this is influenced by their values and beliefs about the science-business relationship. It applies a social-psychological perspective which has hitherto been missing in the literature. The study challenges a common assumption that financial motives are the key drivers of scientists’ commercial activities. It highlights the importance of considering the complex mix of individual-level motives, including the social and intrinsic aspects, in explaining scientists’ commercial behaviour.

In the traditional ‘Mertonian’ world of scientific research (Merton, 1957; 1973), the goal of scientists is to establish priority of discovery by being first to communicate an advance in knowledge and the rewards are the recognition awarded by the scientific community. Peer recognition in the form of publications, citations and prizes, namely, the ‘ribbon’, constitutes the basic form of extrinsic (or social) reward in science from which other extrinsic rewards may be derived, such as career advancement, increase in salaries and enlarged access to research resources. Besides these extrinsic rewards, scientists are also motivated by the intrinsic satisfaction of doing research by solving the ‘puzzle’, creative activity being its own reward (Hagstrom, 1965). Some economists, however, have assumed that scientists, like most economic agents, are interested in money, the ‘*gold’,* as well (Levin and Stephan, 1991; Stephan, 1996). More recently, many authors argue that the growth of entrepreneurial science has brought the reward structures of science and business closer together, resulting in a growing number of academics seeking to ‘cash in’ on their eminence, using the ‘ribbon’ to trade for the ‘gold’ (Stephan and Everhart, 1998; Audretsch and Stephan, 1999; Bains, 2005). There are growing concerns that the ‘gold’ may become a more central component of the motivational calculus of academic scientists, and dwarf the ‘ribbon’. Arguably this can undermine the reputational-based reward system and compromise one of the central institutional elements of academic science (Bok, 2003).

Empirical research on the impact of financial incentives on scientists' propensity to engage in commercialization has provided mixed evidence about the role of money as a motivational driver. While some studies find a positive link between financial incentives and the motivations of inventors to patent (Owen-Smith and Powell, 2001b; Thursby et al., 2001; Lach and Schankerman, 2008), others conclude that monetary rewards offered by universities play no role (Colyvas et al., 2002; Markman et al., 2004). Much of this work, however, has adopted a narrow conception of human motivation based on an economic model and is concerned primarily with the effects of financial incentives on behaviour of academic institutions rather than individual scientists. More recently, some authors (Baldini et al., 2007; Fini et al., 2009; Göktepe-Hulten and Mahagaonkar, 2010) have sought to explore the personal motives behind scientists' transition to academic entrepreneurialism. They found that academics' involvement in commercial activities was not driven by the money incentive so much as the desire to generate research resources and gain reputation. Although these studies have shed light on the importance of non-pecuniary factors, notably the social and reputational rewards associated with the 'ribbon', none has given adequate attention to the intrinsic, 'puzzle-solving' aspect of motivation underlying the behaviours of scientists. Few authors have referred to the work of social psychologists which recognises the multifaceted nature of motivation and the pervasiveness of intrinsic motivation as a powerful driver of action (Deci, 1975; Lindenberg, 2001). Moreover, the question of how scientists' motives for commercial engagement vary according to their values and beliefs remains little understood.

The present study adopts a broader and psychologically richer notion of motivation to incorporate its extrinsic as well as intrinsic aspects. It employs the three concepts of 'gold' (financial rewards), 'ribbon' (reputation and career rewards) and 'puzzle' (intrinsic satisfaction) (Stephan and Levin, 1992) to examine the complex mix of motives driving the behaviour of scientists. The analytical framework builds on theories of motivation in social psychology, notably the self-determination theory (SDT) (Deci and Ryan, 2000; Ryan and Deci, 2000; Gagne and Deci, 2005) which posits that individuals' motives for behaviour and their responses to different kinds of rewards are influenced by the degree of congruence between their personal values and those underlying the activity. Thus, individuals can be extrinsically or intrinsically motivated to different degrees in their pursuit of an activity depending on how far they have internalised the values and regulatory structures associated with it. Self-determination, according to social psychologists, is a critical factor distinguishing intrinsically motivated from externally regulated behaviour. This directs attention to individual agency in the motivational process as actors strive to obtain valued outcomes through intentional behaviours. It also suggests the need to examine closely the perceptions of the individuals and their beliefs about the potential benefits and values of the activities concerned in interpreting the motivations underlying their behaviours. The analysis also draws on the insights of sociology of science literature on the ambivalence of scientists and their divergent value orientations (Merton and Barber, 1963; Box and Cotgrove, 1966; Cotgrove, 1970). The notion of ambivalence underscores the fact that individuals may hold contradictory attitudes towards the same activity and behave in ways that appear to be incompatible with their espoused beliefs or values.

The empirical study presented in this paper comprises 36 in-depth individual interviews and a survey sample of 735 academic scientists from five leading UK research universities. It focuses on two main questions. First, what is the relative importance of the 'gold', 'ribbon' and 'puzzle' as motivators of scientists' commercial pursuits? And second, how does the relative importance of these motivators vary across scientists according to their attitudes and beliefs about the science-business relationship?
It adopts a mixed-method approach, combining qualitative and quantitative methods relating to the same sample as two-thirds of the interviewees also responded to the survey. This enables cross-validation of the findings and deepens insights from the study.

To anticipate the main results, the study finds that the great majority of the scientists are motivated by the traditional rewards of the 'ribbon', using commercial activities as a means to generate resources for their research and professional goals. Personal pecuniary gain, the 'gold', although not irrelevant, is seen as important by a much smaller proportion of the scientists. More crucially, the intrinsic satisfaction derived from commercial engagement itself, as in puzzle-solving, emerges as a central motivation shared by many of the scientists. Beyond this broad picture, the analysis finds significant variation in the motivations across scientists according to their value orientations. The 'traditional' scientists who adhere strongly to the Mertonian norms are primarily extrinsically motivated, using commercialization as a means to support their quest for the ribbon. In contrast, the 'entrepreneurial' scientists who identify most closely with the commercial ethos are intrinsically motivated in their commercial endeavours while also motivated to obtain personal financial gain, the 'gold'. To these scientists, commercial engagement is a volitional, self-determined activity from which they derive personal enjoyment as a form of creative puzzle-solving, and the gold is seen as an integral part of their entrepreneurial achievement. In between these two polar positions, nearly half of the scientists engaged in commercial activities can be described as 'hybrids' who maintain a firm commitment to the core scientific values but also recognise the benefits of commercial engagement for their scientific goals. Besides the extrinsic rewards of the ribbon, these scientists are also strongly intrinsically motivated in their commercial endeavours which appear to satisfy their intellectual curiosity personally as well as the desire for doing good socially.

This study focuses on the social-psychological dynamics of scientists' motivations for commercial engagement and shows how motives for behaviour vary according to their personal values and beliefs. It contributes not only to research on scientific motivation and academic entrepreneurialism but also has important implications for policy makers seeking to promote commercial exploitation of research. In particular, it demonstrates that there is no one single ideal type of 'entrepreneurial' scientists marked by the desire for one particular kind of reward on its own. It is therefore unlikely that an undifferentiated approach focusing on extrinsic financial rewards will be effective in eliciting the requisite effort across the board.

The remainder of the paper is structured as follows. The next section outlines the changes in the institutional context associated with the entrepreneurial university. The third section develops a theoretical framework on the relationship between scientists' value orientations, the different types of motivations on the self-determination continuum and the salience of gold, ribbon or puzzle as desired outcomes of commercial engagement. This is followed by a section which introduces the research methods and the key variables used in the empirical analysis. Section five examines the relationship between the motivating factors and scientists' propensity to engage in commercial activities. A further section explores the diverse value orientations of those engaged in commercial activities and the salience of the different motivating factors. The paper ends by discussing the theoretical and policy implications.

2. THE INSTITUTIONAL CONTEXT

The notion of the 'entrepreneurial university' that stresses knowledge capitalization has become a powerful force that has shaped the governance of universities and work experiences of academic scientists in recent years. In the U.K., the government's science and technology policy over the past two decades has sought to exploit the scientific knowledge base for innovation and economic competitiveness by promoting stronger collaboration between university and industry, and stimulating academic entrepreneurship (DTI, 2000; Lambert, 2003). At the same time, universities themselves have become willing actors in a range of markets in response to growing constraints on public funding and to adapt to a more competitive environment (Slaughter and Leslie, 1997; Henkel, 2007). Many are experimenting with new modes of governance and institutional practices to engage in commercial exploitation of research.

The institutional transformation associated with the entrepreneurial university has broadened the acceptable roles of academic researchers to accommodate engagement in commercial activities. In parallel with the traditional 'Mertonian' model that emphasises disinterested research, an alternative model of academic entrepreneurialism that encourages commercial exploitation of research has gained prominence in recent years. Some authors argue that the rules that govern achievement and competition in the world of academic science have changed in recent years to incorporate commercial outcomes (Slaughter and Leslie, 1997; Owen-Smith, 2003). A potential consequence of this is to bring the reward structures of two previously separate institutional spheres of science and commerce closer together, opening up the possibility for scientists to translate scientific credits across the two arenas. In the face of these developments and a normative duality that now governs university research, scientists may find themselves torn between the traditional Mertonian ideals of basic science and the reality of an encroaching market-oriented logic. While some may seek to resolve the tension by making choices between the dichotomous alternatives, others may attempt to reconcile the polar positions by re-negotiating their roles at the intersection of the two domains (Owen-Smith and Powell, 2001a; Murray, 2006). Scientists' engagement in commercial activities will therefore need to be interpreted within this shifting institutional context in which individual action often reflects the contradiction experienced rather than necessarily signalling unequivocal acceptance of a particular set of norms or values.

Early research in the sociology of science drew attention to the 'sociological ambivalence' of scientists and the frequent deviation of their actual behaviour from the default Mertonian ideals (Mitroff, 1974; Latour and Woolgar, 1979). Gieryn (1983) coined the term 'boundary work' to denote the active agency role of scientists in drawing and redrawing the boundaries of their work in pursuit of professional autonomy and increased resources. His analysis showed that the boundary between basic and applied research was clearly established when the scientific community wanted to protect its professional autonomy. However, it often became obscure, if not dissolved, when scientists sought to secure and justify increased resources and public support for scientific research. Thus scientific work can be at once pure and applied; and the boundary between the production of knowledge and its exploitation can be clearly demarcated or blurred. This ambiguity is a source of internal tension, as well as giving scientists much opportunity for choice and variation. The contemporary transformation in the relationship between science and business has brought the sociological ambivalence of science to the forefront and opened up new opportunities for individual action at the increasingly blurred boundary between the two sectors.

Recognising this marked ambivalence in scientific work is essential for understanding the complex relationship between values and behaviours because it implies that scientists' adherence to traditional 'Mertonian' norms does not preclude involvement in commercial activities and commercial engagement does not necessarily signal their acceptance of its underlying ethos. The same outward behaviour of commercial engagement may be underpinned by diverse attitudes and motives. Shinn and Lammy (2006), for example, identify three categories of academic researchers who pursue divergent paths of commercialization: the 'academics' are those who weakly identify with the firm but may create a business venture for instrumental reasons; the 'pioneers' are driven by economic as well as scientific considerations; and the 'janus' are the hybrid type driven primarily by their passion for scientific knowledge production. Scientists who participate in commercial activities do not constitute a homogeneous category and hence the need to adopt a differentiated approach for understanding their motivations.

3. THE THEORETICAL FRAMEWORK

3.1 The Social Psychology of Human Motivation: Self-Determination Theory (SDT)

The work of social psychologists on motivation, notably self-determination theory (SDT) (Deci and Ryan, 2000; Ryan and Deci, 2000; Gagne and Deci, 2005), provides a useful lens for examining the multifaceted nature of human motivation and its relationship with social values and norms. It treats motivation as the outcome of interaction between external regulatory processes and individuals' internal psychological needs for autonomy and self-determination. Taking the view that people are moved to act when they believe that the behaviours will lead to desired outcomes, SDT differentiates the content of outcomes and the regulatory processes through which they are pursued and thus predicting variation in the motivation underlying behaviours. Moreover, its emphasis on self-regulation in the motivational process is particularly germane to the case of academics who enjoy considerable freedom in their work.

SDT distinguishes three main states: intrinsic motivation, extrinsic motivation and amotivation. Intrinsic motivation refers to doing something for its inherent pleasure and satisfaction, whereas extrinsic motivation refers to doing something for a separable outcome or external rewards. Amotivation means having no intention to act because of lack of interest or not valuing the activity (Ryan, 1995). SDT posits that an individual's motivation for behaviour can be placed on a continuum of self-determination (see Figure 1). It ranges from amotivation, which is wholly lacking in self-determination to intrinsic motivation which is an archetypal self-determined behaviour because it arises from the individual's spontaneous interest rather than driven by external control. Between the two poles, extrinsic motivation can vary in its degree of self-determination, ranging from behaviour that is fully externally regulated to one that is partially or fully internally integrated which approximates intrinsic motivation. Central to SDT is the argument that extrinsically motivated behaviour can be transformed into intrinsically motivated one as individuals internalise the values and behavioural regulation that underlies it. When this occurs, the behaviour becomes autonomous and no longer requires the presence of an external reward.

Building on the basic tenet that human beings have innate psychological needs for autonomy, SDT sees internalization as 'an active, natural process in which individuals attempt to transform socially sanctioned mores or requests into personally endorsed values and self-regulations' (Deci and Ryan, 2000: 235). As such, SDT stresses individual agency in the internalization process in that it is not just something that the socializing environment does to individuals but also represents the means through which individuals actively assimilate and reconstitute external regulations into inner values so that the individuals can be self-determined while enacting them (Ryan, 1993). SDT identifies three distinct processes of internalization: introjection, identification and integration, which represent different degrees or forms of regulation associated with the different motivational types (mix) on the continuum of extrinsic-intrinsic motivation (Deci and Ryan, 2000). *Introjection* occurs when individuals partially take in an external regulation but do not accept it as their own and therefore the behaviour is not congruent with their values and is not self-determined: it is a partially 'controlled' activity and is predominately extrinsically motivated. *Identification* occurs when individuals identify with the value of behaviour for their own self-selected goals and they experience greater freedom and volition because the behaviour is more congruent with their personal goals and identities. Identification makes the behaviour more autonomous and moves it towards the intrinsic end of the continuum. The most complete form of internalization is *integration* which occurs when individuals completely identify with the importance of social regulations or values, assimilate them into their sense of self and accept them as their own. As the behaviour becomes fully congruent with the individuals' values and identity, they can be intrinsically motivated by it in the absence of an external regulation.

By focusing on the variation in the level of internalization and its relationship with the extrinsic and intrinsic aspects of motivation, SDT suggests that there are different kinds and degrees of motivation between the two polar types. There are three broad categories of outcomes associated with the different types of motivation: material, social and affective. While material outcomes are primarily related to extrinsic motivation, affective outcomes are closely related to intrinsic motivation. Social outcomes, however, are related to the ‘in-between’ types of motivation such as introjection (to fit in or feel worthy) and identification (to act appropriately). In contrast to the canonical economic model of human motivation and behaviour which stresses the efficacy of extrinsic financial rewards, social psychologists argue that social and affective outcomes are equally salient. In fact, by postulating that human beings have a general organismic tendency towards self-regulation (Ryan, 1995), social psychologists stress the potency of intrinsic motivation in driving behaviours. Although the concept of intrinsic motivation is often linked to affective outcomes, it has recently been broadened to incorporate a social, normative dimension (Grant, 2008). Lindenberg (2001), for example, makes a distinction between enjoyment-based and obligation-based intrinsic motivation. The former is tied to the emotion for the improvement of one’s condition whereas the latter refers to the satisfaction derived from acting according to a rule, norm or principle. In both cases, the motivation driving the behaviour can be said to be intrinsic because it arises in the absence of material rewards or external constraints.

It should be noted that behaviours often lead to a combination of different outcomes. An intrinsic interest in the activity does not necessarily rule out the salience of extrinsic rewards insofar as the perceived locus of causality of the activity lies within the individual (Deci, 1975). Although some authors argue that money rewards can undermine intrinsic motivation due to psychological substitution effects (e.g. Frey, 1997), others suggest that some highly autonomous individuals (e.g. creative artists or scientists) may be strongly intrinsically interested in the activity and, at the same time, be strongly motivated to acquire extrinsic rewards (e.g. recognition, careers and money) for that activity (Amabile et al., 1994). Deci et al (1999: 658) point out that ‘the effects of external rewards on behaviours necessitate a differentiated analysis of how the rewards are interpreted by the recipients’. All these highlight the need to consider scientists’ perceptions and beliefs about the potential benefits of commercial engagement in interpreting their motives for the behaviour.

3.2 Scientific Motivation and Commercial Engagement: Ribbon, Gold and Puzzle

Scientists may be motivated by a complex array of pecuniary and non-pecuniary factors in their commercial pursuits. A characteristic feature of the scientific reward system is its multidimensional nature, comprising the three components of the ‘ribbon’, ‘gold’ and ‘puzzle’ (Stephen and Levin, 1992). In the Mertonian world of academic science, the ribbon is the most substantial part of scientists’ rewards. This is not only because scientists are strongly motivated by the recognition and prestige bestowed by their professional peers but also, other rewards such as salary and research funds are usually graduated in accordance with the degree of recognition achieved (Mulkay and Turner, 1971; Stephan, 1996). The ribbon is a deeply institutionalized feature in the scientific reward system and scientists feel the effects of the drive (Hagstrom, 1974; Hong and Walsh, 2009). Within the traditional model, publication is the main currency in the exchange relationship for the ribbon. The growing influence of the entrepreneurial paradigm may be subtly changing the ribbon exchange relationship to incorporate certain forms of commercial science. Several authors point out that contemporary academics can use patents as an alternative currency for building cycles of credit for obtaining resources to further the traditional rewards (Murray, 2006; Owen-Smith and Powell, 2003). Others suggest that the increasing reputational returns associated with patenting may prompt some scientists to use commercial activities as a means to further their academic careers (Krabel and Mueller, 2009).

Although personal pecuniary gain, the 'gold', is also a component of the scientific reward system, it is predominately a consequence of the ribbon, and not a direct incentive for research in academic science (Stephan, 1996). The rise of entrepreneurial science may well have opened up opportunities for scientists to reap financial rewards from commercial activities. It is, however, not entirely clear whether, and to what extent, the 'gold' is a motivational driver in the first place. There is a longstanding controversy in motivation theory about the role of money as a motivator (Sachau, 2007). Herzberg's (1966) 'motivation–hygiene theory' and more recently authors in the field of positive psychology (Seligman and Csikszentmihalyi, 2000) argue that money is a hygiene factor, not a motivator. It contributes to individual satisfaction or dissatisfaction but may not have the power to motivate on its own.

Beyond the extrinsic rewards of the ribbon and the gold, the majority of academic scientists are intrinsically motivated to advance knowledge, and they also derive immense satisfaction from engaging in challenging and creative activities. Indeed, the desire to engage in creative puzzle solving is the hall mark of a dedicated scientist (Eiduson, 1962; Cotgrove, 1970). In the Mertonian world of basic science, scientists derive satisfaction and enjoyment from seeking and finding vital truths within a relatively bounded scientific community. According to this view, there is no reason why the pursuit of creativity and puzzle solving should not take place in the context of an orientation towards knowledge application and entrepreneurial engagement.

The different motivational drivers can co-exist and scientists may be extrinsically or intrinsically motivated to different degrees in their pursuit of commercialization. The university is a professional bureaucracy where academics are accorded a relatively high degree of autonomy and they can choose whether to engage with industry. Few would be doing it as a result of external compulsion but the individuals' sense of pressure or willingness to participate in commercial activities may vary according to their beliefs about the values and potential benefits of such activities. Existing research has shown that scientists differ in their degree of attachment to the traditional 'Mertonian' values (Box and Cotgrove, 1966; Hermanowicz, 1998) and hold varied beliefs about the appropriate relationship between science and commerce (Owen-Smith and Powell, 2001a; Renault, 2006). Thus, their motives for pursuing commercial science will vary.

Figure 1 summarises the main points of the theoretical framework. It postulates that commercial engagement can be either a 'controlled' or 'autonomous' activity depending how far scientists have 'internalised' the values associated with it. Scientists who adhere strongly to the traditional Mertonian norms of basic science will perceive commercialization to be at odds with their personal values and goals, and the majority are likely to be *amotivated*. However, some may take part in the activity as a result of *introjection*. These 'traditional-oriented' scientists can be placed at the extrinsic end of the motivational continuum and may use commercialization as a means to obtain resources (e.g. research funding) to support their pursuit for the ribbon. In contrast, other scientists may pursue the activity volitionally out of a sense of personal commitment or interest because they have fully *integrated* the norm of entrepreneurialism. They could be motivated to do what is actually in their own interest and the desired outcomes could be both affective and material. The financial returns in this case could represent both achievement and profit. This type of 'entrepreneurial-oriented' scientists can be placed at the intrinsic end of the continuum. Between the polar opposites, there are reasons to expect some scientists to hold an ambivalent attitude towards commercial activities and adopt a 'hybrid' position encompassing characteristics of the 'traditional' and 'entrepreneurial'. Owen-Smith and Powell (2001a: 4) argue that individual academics' choices in response to the entrepreneurial academic paradigm 'have created a myriad of positions that are neither old nor new school, but instead combine characteristics of both'. In a study of scientists' role transition to academic entrepreneurs, Jain et al (2009: 927) observe that this process typically involves crafting a hybrid role identity in which scientists 'overlay elements of a commercial orientation onto an academic one'. This is similar to the process of *identification* described in SDT through which people identify with the value and importance of behaviour for their self-selected values (Ryan and Deci, 2000). These scientists can be placed mid-point on the motivational continuum - they may be extrinsically motivated somewhat while at the same time intrinsically motivated in their commercial pursuits.

Figure 1 about here

4. RESEARCH METHODS AND DATA

4.1. Data Collection and Sample

The study used a combination of in-depth individual interviews and an on-line questionnaire survey. The sample consisted of scientists from five major U.K. research universities working in the fields of biological sciences, medicine, computer science and engineering, and physical sciences (including chemistry, physics and mathematics). Previous studies suggest that research commercialization tends to be concentrated among eminent scientists in top-ranked departments or universities (Zucker et al., 1998; Di Gregorio and Shane, 2003). This study sampled scientists from the universities where opportunities for commercialization of fundamental research are plentiful. It includes three universities which are among the top five UK universities in terms of their research budgets and size of science faculties, and two smaller universities with centres of research excellence in the relevant disciplines. All the five universities have well-established organisational units supporting knowledge transfer to industry and incentive schemes to encourage academics to engage in commercial activities. Thus, the sample is oriented towards the elite academic researchers operating in an environment in which they have the options to make a meaningful choice between traditional Mertonian goals and those of commercial engagement.

The first phase 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, contract research, personal consultancy, joint publications and student sponsorships) to direct involvement in commercial activities (e.g. patenting, licensing, spin-off company affiliation or formation). Although the main focus of the study is on the latter category, the former provides a reference group for the analysis. The individuals were identified mainly through CV searches on the universities' websites. A snowball method was also used to obtain additional names. A total of 36 academic scientists were interviewed. These were all senior academics in tenured positions, mostly professors. It should be noted that this is a selective sample as the majority took part in the study had substantive industrial links and commercialization experience: 10 were engaged solely in collaborative links, and 26 were engaged in a range of collaborative and commercial activities including 16 spin-off company founders and 3 affiliates. The sample is therefore skewed towards those with an 'entrepreneurial' orientation and serves as a critical group for testing the 'academic capitalism' argument.

The objectives of the interviews were twofold. First, they sought to obtain rich qualitative data to help interpret the meanings that actors attribute to actions and relationships which cannot be easily captured by a questionnaire survey. And second, they served as a pilot for exploring and testing the relevant questions for the survey. The interviews used a semi-structured questionnaire focussing on the scientists' industrial links experience, their attitudes and orientations towards science-business relations and research commercialization. Those who were actively engaged in industrial links were asked detailed questions about their interface with industry, the reasons and motivations for the involvement and assessment of the rewards and benefits of these activities. Most of the interviews took place in 2006. 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.

Following the interviews and initial data analysis, an on-line questionnaire survey was implemented in early 2007. The web-based questionnaire was e-mailed to about 3,100 academics, following a successful pilot. The sample population included all academic staff of the disciplines mentioned above and principal investigators of the related major research units listed on the universities' websites, excluding post-doctoral researchers and research assistants.[1] 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 across disciplines, indicating a degree of consistency in the response patterns. Similar to the interviews, the responses were likely to be skewed towards those more actively engaged in industrial links as these academics might have felt more motivated to respond to the survey.

The distribution of the interview and survey samples by discipline is shown in Table 1.

Table 1 about here

4.2. Analytical Approach and Main Variables

This study adopts a mixed-method approach and the qualitative and quantitative data are integrated iteratively at the interpretive level. The qualitative analysis informs the organization of the key variables used in the quantitative analysis and is also used to elaborate more fully the survey results.

The survey questionnaire contained questions on various aspects of scientists' industrial links activities, their motivations and attitudes. The main variables used in the quantitative analysis are derived from the questions concerning: a) the nature of their involvement in different types of industrial links; b) their value orientations towards academia-industry interface; and c) the factors motivating them to engage with industry.

4.2.1. Modes of engagement with industry: collaborative and commercial

The scientists were asked to indicate if they had been involved in any industrial links activities over the last 10 years (multiple answers). Nearly three-quarters (73%) reported that they had involvement in industrial links of one kind or another, of which 39 percent were engaged in collaborative activities only and 34 percent also participated in commercialization. Among those engaged in commercialization: 30 % held patents, 10 % had been involved in licensing, 17% reported affiliation with start-ups and 14% had founded their own companies. It is important to note that collaborative and commercial modes of engagement are not discrete activities as the majority of scientists interface with industry through multiple channels. More notably, the majority of those engaged in commercial activities also had extensive involvement in various collaborative links. However, involvement in commercialization often brings controversies as it is seen as the incorporation of a 'profit motive' in academic science. Thus, a distinction is made between two different modes of engagement in the quantitative analysis: the 'collaborative' category refers to those engaged in collaborative activities only, and the 'commercial' category includes those involved in commercial activities.[2]

4.2.2. Value orientations and attitudes towards commercial engagement

The interviews found a great deal of variation in the scientists' attitudes and beliefs about academia-industry collaboration and their perceived legitimacy of commercialization. Their value preferences and dispositions with regard to commercial engagement revealed four 'orientational categories'.[3] The categorisation places the scientists on a continuum defined by two polar sets of values: the 'traditional' versus the 'entrepreneurial'.

These four categories were initially derived inductively from the interviews and later cross checked against the survey data. In the interviews, the scientists were asked detailed questions about their views on the interface between science and business, and how they interpret and evaluate their own positions and industrial links activities. At the end of the interviews, they were shown a card with four statements describing different beliefs and value preferences and rationales behind academia and industry collaboration (see, Appendix Table A1). The scientists were asked to select one statement that best described their own 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 described their orientations. The distribution of the responses shows that in the great majority of cases, the second choice was contiguous to the first which illustrates the consistency of the choices. The first choice category is adopted for the quantitative analysis (Appendix Table A1). The distribution of the interview and survey samples by the four orientational categories is shown in Table 2. 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 2 about here

In this classification, there are two categories of traditional-oriented scientists, referred to as *Type I 'pure traditionalists'* and *Type II 'pragmatic traditionalists'*. Both are characterised by a belief that academia-industry should remain distinct but differ in their inclination to engage in commercial activities. *Type I pure traditionalists* defy the growing pressures for commercialization and contest its legitimacy. They may develop some collaborative links with industry but typically have no intention to pursue commercial activities and can be said to be *amotivated*. *Type II pragmatic traditionalists* adopt a more accommodating attitude and recognise a need to meet the growing institutional expectations for commercial engagement. They are prepared to experiment with commercial practices in anticipation of possible benefits. However, commercial engagement does not sit uncomfortably with their values and tends to cause much inner conflict. A Type II bioscientist, for example, mocked his own activities in seeking company funding by repeatedly saying that he was 'selling his soul…'. These scientists do not identify with the values of commercialization and their participation in commercial activities reflects *introjection*.

At the opposite pole are the Type IV *'entrepreneurial scientists'* who see the boundary between academia and industry as entirely permeable, and they believe in the fundamental importance of science-business collaboration for knowledge application and commercial exploitation. To them, science is inherently commercial and the pursuit of commercial science is entirely logical and compatible with their academic role. For example, one professor described 'entrepreneurial engagement' as part of 'the repertoire, base skills' that he should retain as a professional scientist. Another saw the parallel activities in the academic and commercial arenas as an integral part of his professional role: '…it's part of my life, you know, it's not dislocated particularly'. These entrepreneurial scientists appear to have fully accepted the norm of entrepreneurialism which can be taken to represent *integration* on the self-determination continuum.

Between the 'traditional' and 'entrepreneurial', there is a mixed category of scientists, referred to as Type III 'hybrids'. These scientists share the entrepreneurial scientists' belief in the importance and benefits of science-business collaboration, while maintaining the traditionalists' commitment to the core scientific values. However, unlike the traditionalists, the hybrids did not appear to experience psychological discomfort when they embarked on commercial ventures. They perceived such endeavours as largely legitimate and desirable for their scientific pursuits. Forming a spin-off company, for example, was seen as a way of maintaining their scientific autonomy and asserting control over the knowledge exploitation process so as to exclude unwanted commercial interests from big companies. They seek *identification* with commercial activity by reconstituting its meaning so that it becomes more congruent with their professional goals and values.

Previous research suggests that scientists' personal values and their beliefs about the benefits of commercialization influence their entrepreneurial behaviour (Renault, 2006; Krabel and Mueller, 2009). Table 3 shows that there is a strong association between the value orientations of scientists and their engagement in different types of industrial links. As expected, very few Type I pure traditionalists have commercial engagement whereas those displaying a Type IV 'entrepreneurial' orientation are more likely to be involved in commercial activities. However, beyond this broad overall pattern, two observations are notable. The first is that the Type III 'hybrid' category constitutes the largest category (47%) among those engaged in commercial activities. The second point is that a significant proportion (30%) of those engaged in commercial activities display a Type II 'pragmatic traditional' orientation. Even in the case of the company affiliates/ founders, who are most emblematic of the penetration of 'academic capitalism' into academia, about one-third see themselves as traditionalists and only one-fifth identify themselves as 'entrepreneurial' scientists. Half of the company affiliates/founders fall in the 'hybrid' category.

These observations suggest that scientists' engagement in commercial activities may be driven by diverse and mixed motives. Given the very small number of Type I scientists involved in commercial activities, these are merged with Type II to form a single category of 'traditional' scientists in subsequent analysis.

Table 3 about here

4.2.3. The motivating factors: 'gold', 'ribbon' and 'puzzle'

In the survey, respondents who had been engaged in industrial links were asked to score the relevance/importance of eight factors that had motivated them to pursue the activities.[4] Each factor is ranked on a four-point scale: (1) 'not relevant', (2) 'slightly relevant', (3) 'important' and (4) 'very important'. Table 4 presents the descriptive results, showing the breakdown by the modes of industrial engagement and among those engaged in commercial activities, by their value orientations. Three points are worthy of note. First, funding/research resources appear at the top of the motivational hierarchy whereas personal income is at the bottom. Second, those engaged in commercial activities attached greater importance to nearly all the items, notably the knowledge-related factors, compared with those involved in collaborative activities. Personal income is low in the motivational hierarchy for both categories but a significantly higher proportion of those engaged in commercialization scored this as an 'important/very important' factor. And third, there is significant variation in the relative importance attached to the different items across the three categories of scientists engaged in commercial activities. While the Type II 'traditional' scientists were driven primarily by the funding/resource factor, the Type III and IV scientists attached high importance also to a broad array of knowledge, networking and reputational factors. It is also notable that 'intellectual curiosity' was seen as an important factor by a significant proportion of the two latter categories. The Type IV scientists were most likely to acknowledge the importance of personal income, with 59 percent agreeing that this was an important/very important motivating factor.

Table 4 about here

A correlation matrix was computed on the eight motivating factors which showed high correlations between the responses to some of the questions. To determine the common dimensions underlying them and for the purpose of data simplification, a factor analysis (principal component analysis – PCA) was performed on the eight items used in the questionnaire. Five factors which best represent the principal motivations as emerged from the interviews were extracted. The descriptive statistics and the PCA results are shown in Table 5. The first factor, labelled ***Reputation***, groups the three items relating to external reputation building and networking and is categorised as a *Ribbon* motivator. Scientists are motivated to achieve prestige and recognition not only among their academic peers but also increasingly seek to do so through broadening their extra-academic network ties. Some of the scientists interviewed also pointed out that building links with firms helped to provide job opportunities for post-doctoral researchers and graduate students which could enhance their reputation, resulting in a 'virtuous circle' of attracting promising young researchers into their laboratories.

The second and third factors, referred to as ***Knowledge*** and ***Curiosity*** respectively, include the items pertaining to the intrinsic satisfaction derived from engaging in knowledge application/transfer and the fulfilment of intellectual curiosity. These are classified as *puzzle*-related, intrinsic motivators, comprising the social as well as personal dimensions (Lindenberg, 2001). While 'satisfaction of intellectual curiosity' is clearly a personal, intrinsic motivation, it may not be immediately apparent that 'knowledge application/ exchange' is also related to intrinsic motivation. Some scientists may adopt an instrumental stance and seek to exploit knowledge for pecuniary gain. However, this does not preclude the salience of non-pecuniary motivations. In fact, many of the scientists interviewed, notably the Type III hybrids, regard knowledge application as an extension of their scientific role in pushing the boundaries of science. Some saw commercialization as a means of realising the wider social impact of their research. This is similar to what some refer to as 'public service' or 'prosocial' motivation, an intrinsic work attribute shared by many professional groups (Andersen and Pallesen, 2008). According to Lindenberg (2001, p.335), this type of obligation-based motivation is a type of intrinsic motivation as the individuals 'act on the basis of a principle and they do not pursue an external reward'.

The fourth and fifth factors appear as separate items on their own. Factor 4 ***Income*** illustrates the 'for-profit' motive, the *Gold*. The interviews suggest that many scientists develop links with firms for funding and other resources to support their research. Thus, factor 5 ***Funding/ Research Resources*** is closely related to the expectation of scientific recognition and rewards associated with the *Ribbon.*

Table 5 about here

5. MOTIVATING FACTORS AND COMMERCIAL ENGAGEMENT: REGRESSION ANALYSIS

Having identified the main motivating factors, a binary logistic regression was conducted to examine the relative importance of the five motivating factors for scientists' engagement in commercial activities. The latter was taken as the dependent variable, with commercial engagement coded as one and, otherwise (collaborative engagement only) coded as zero. Several control variables likely to influence the propensity of scientists to engage in commercialization were included in the regression. First, scientists engaged in basic research may be less inclined to commercialise their research relative to those involved in applied research. So a dummy variable was included for engagement in basic research. Second, it has been widely acknowledged that the scientific discipline constitutes an important work context that influences scientists' work orientations and entrepreneurial behaviours (Meyer-Krahmer and Schmoch, 1998; D'Este and Patel, 2007). The norms, history of industrial engagement and market opportunities for knowledge exploitation diverge between different fields of research. Thus, dummy variables were included to control for variation across the following disciplines: biosciences, medicine, computer science/engineering, chemistry and physical sciences (the reference category).[5]

In addition, three variables reflecting the experience of the individuals were included in the estimation. Younger academics may be more open to commercialization because they are less embedded in the academically-focused career tracks and may have already been socialised into the emerging entrepreneurial paradigm (Owen-Smith and Powell, 2001a; Ambos et al., 2008). Thus, an age dummy was included in the regression with those age 40 or under coded as one and otherwise zero. Prior work experience can influence scientists' orientations towards commercial engagement and those who move from industry to pursue an academic career may display a stronger entrepreneurial orientation (Lam, 2007; Krabel and Mueller, 2009). A dummy variable for prior industrial experience was included in the regression: those who had previously worked in private industry were coded one and otherwise zero. Finally, academic life cycle theory suggests that scientists invest in the development of their human capital and reputation early in their careers and seek to obtain financial returns by engaging in entrepreneurial activities when their career goals have been achieved (Levin and Stephan, 1991; Audretsch and Stephan, 1999). Thus one might expect established academics to have a greater propensity to engage in commercial activities. An additional control variable on career stage, whether the scientist is a professor, was also included. Descriptive statistics and correlation matrix of the variables are shown in Appendix Table A2.

Table 6 provides the results of the first regression. Model 1 shows the relationship between the motivating factors and commercial engagement as the dependent variable, and Model 2 includes the control variables. The factors that are positively and significantly associated with commercialization, in order of the strength of the coefficients, are: personal income (0.571), knowledge (0.514) and funding/research resources (0.266). The 'reputation/networking' factor is negatively associated with commercial engagement (-0.328). The coefficient for the 'curiosity' factor is not statistically significant. These results suggest that relative to those involved in collaborative activities only, scientists engaged in commercialization are more strongly motivated by the 'for-profit' motive of the 'gold', as well the desire for knowledge application/transfer (the 'puzzle'). Obtaining funding for research (the 'ribbon') is also important but differentiates the two groups to a lesser degree. Those engaged in collaborative activities only, on the other hand, attach far greater importance to reputation building and networking (the 'ribbon'). This is not surprising given that collaboration is primarily a relationship-based, 'open science' channel of industrial engagement. These results support the argument that scientists' have multiple motives for commercialising their research and the 'gold' is one amongst other non-pecuniary motivational drivers behind their commercial pursuits.

With regard to the control variables, research disciplines and age have a significant influence on the likelihood of commercialization. As expected, those in medicine, biosciences, computer science/engineering and chemistry are more likely to engage in commercialization than those in the reference category of physical sciences. Younger scientists (age <40) are less likely to participate in commercialization. While these scientists may adopt a more open attitude towards commercialization as argued by some (Ambos et al., 2008), they are relatively less experienced and may have less expertise to 'sell' than the older, more established scientists. The other three control variables, basic research, professor and previous industrial experience are not significantly associated with commercial engagement, suggesting that scientists with these characteristics are just as likely to be involved in collaborative as in commercial activities. This may seem counter-intuitive but one possible explanation is that those experienced scientists with an established track record of industrial links are just as likely to be involved in collaborative as in commercial activities. The control variables do not alter the significant relationship between the motivators and commercial engagement.

Table 6 about here

6. DIVERSE VALUE ORIENTATIONS AND MULTIPLE MOTIVES

This section uses compare means analysis and the interview data to examine if there are significant differences in the motives for engaging in commercial activities across the three categories of scientists.

Table 7 compares the mean scores of the five motivating factors across the three categories of scientists and the T-test results of pair-wise comparisons. The results of ANOVA show significant variation in the relative importance of the different motivating factors across the three categories. With regard to the 'knowledge', 'income' and 'funding' factors, the variation is significant at 0.001 level and for the 'curiosity' factor, at 0.05 level. There is no significant difference with regard to the 'reputation' factor which is generally a less important motivator for those engaged in commercial activities relative to those involved in collaborative links (see Table 6).

Turning to the results of the two sample comparisons, firstly, between the two polar categories of the 'traditional' and 'entrepreneurial', the T-test shows that the 'funding factor' (*ribbon*-related) is significantly more important for the former while 'personal income' (the *gold*), for the latter (both significant at the 0.001 level). The 'knowledge' factor (*puzzle*-related) is marginally more important for the 'entrepreneurial' than the 'traditional' scientists (at the 0.1 level). Secondly, the comparison between the 'hybrid' and 'traditional' categories shows that the two *puzzled*-related factors, 'knowledge' (at the 0.001 level) and 'curiosity' (at the 0.01 level) are significantly more important for the former, suggesting that the hybrids are driven by a stronger desire for knowledge application/transfer and an intrinsic, personal curiosity in their pursuit of commercial activities. Finally, comparing the 'hybrid' with the 'entrepreneurial' category also shows that they differ significantly (at the 0.001 level) with regard to the 'funding' and 'income' factors. The hybrids, like the traditionalists are significantly more motivated by 'funding' and less motivated by 'income'. These comparisons indicate that one key factor that distinguishes the 'entrepreneurial' scientists from the other two categories is the importance of personal income. It should be noted that there are no significant differences between the 'entrepreneurial' and 'hybrid' categories with regard to the 'knowledge' and 'curiosity' factors, suggesting that these are common intrinsic motivators for both categories.

Simplifying somewhat and using the extrinsic-intrinsic constructs, one might distinguish the motivational orientations of the three categories as follows: a) the 'traditional' scientists are predominately extrinsically motivated, using commercial engagement as a means to obtain funding resources to support their quest for the ribbon; b) the 'hybrids' appear to be most intrinsically motivated by the puzzle (knowledge application and curiosity) as well as by the extrinsic rewards of the ribbon; and c) the 'entrepreneurial' scientists appear to be most strongly motivated by the gold and also, to some extent, by the intrinsic satisfaction of the puzzle. These results support the main thrust of the SDT argument about the relationship between value orientations and motivations. However, there is one apparent anomaly: the entrepreneurial scientists do not seem to be more intrinsically motivated then the hybrid category despite their stronger identification with commercial activities. Given that intrinsic motivation has social and affective dimensions, the survey results may not have fully captured both aspects. The in-depth interviews will shed light on this and provide a more fine-grained account of the general picture emerging from the statistical analysis.

6.1. The Traditional Scientists as 'Reluctant' Commercializers: the 'Ribbon'

The traditional scientists are 'reluctant' commercializers who pursue commercial activities mainly to obtain the much needed funding for research in an increasingly resource constrained environment. The reply of a Type II professor to the question of what drove his group to form a spin-off company is illustrative: '*We just wanted to test our ideas. We were desperate to get funding…Well – so none of us are born again entrepreneurs. We were driven by the idea we wanted to do this research and to use it…*'. Besides funding, there is also evidence suggesting that some traditional scientists are motivated by the possibility of using commercial engagement as a currency for building scientific credit and enhancing their academic careers. Some recognised that commercial engagement had gained increased institutional legitimacy and it was something that might bring academic credentials. One Type II scientist involved in a start-up company and who had just been awarded his professorship at the time of the interview, pointed out that commercial engagement was '*a risk worth taking*' because '*it was the culture of the department*' and that '*if you were going to be a top academic, that's one of the things that you had to cover …*'.

To the traditional scientists, commercial engagement represents an introjected and extrinsically motivated behaviour. Introjection, according to social psychologists (Koestner et al., 1996), is associated with emotional incongruence and ambiguity and is a relatively unstable form of regulation. Evidence based on the interviews suggests that the position of the traditionalists was somewhat indeterminate and they would change directions based on evaluations of the success or failures of their trial efforts. Several of the traditional scientists interviewed, for example, 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. Some expressed regret at their commercial involvement. One survey respondent, for example, wrote on the questionnaire: '*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*' (Type II Professor, biosciences). These accounts suggest that scientists' transition to academic entrepreneurialism is not necessarily a linear process but can be halted or even reversed when commercial engagement proved to be of limited value for furthering their quest for the ribbon.

6.2. The Hybrid Scientists as 'Strategic' Commercializers: the 'Ribbon' and 'Puzzle'

Unlike the traditionalists, the hybrids participate in commercial activities more autonomously, supported by feelings of identification. Besides funding, the hybrid scientists are also strongly intrinsically motivated in their commercial pursuits. The majority interviewed believed in the positive benefits of knowledge application (e.g. testing new ideas) and saw commercialization as an extension of their knowledge search activities. The following quote is indicative: ' *…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…*'. To these scientists, commercialization represents an additional avenue for realising the wider potential of their particular science. Many interviewees talked about 'the challenge' of solving complex industrial problems and '*the rewards that come with it can be intellectual, academic as well as financial*', to put it in the words of one Type III professor. To these scientists, knowledge application through taking part in commercial ventures represents a kind of puzzle-solving activity that satisfies their 'intellectual curiosity'. The assumption that scientists derive the pleasure of puzzle-solving only from basic research is based on a narrow conception of the full range of creative scientific activity in their work.

The hybrid scientists' personal interest in knowledge application also appears to bolster a strong professional conviction to make their knowledge socially relevant. This is particularly notable among those researching in the life-sciences. The following reply of a company founder to the question of why forming the spin-offs is indicative: '*...I think 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…*' (Type III professor, biosciences). Another biomedical professor made a similar comment: '*…we wanted to see if, you know, there was a potential new drug there for, you know, treating people who can't get treated with anything else...*' Grant (2008) argues that personal interest in an activity can reinforce pro-social intrinsic motivation which is a particular form of intrinsic motivation based on a desire to help others resulting from identified regulation.

The hybrid scientists can be described as 'strategic' commercializers in that they incorporate commercial practices into their repertoire of behaviour without sacrificing their focal academic identity. They will attempt to influence or manipulate the expectations of their industrial partners in order to shape the relationships. As one Type III professor 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*'. They seek to resolve the cognitive dissonance resulting from the conflicting logics of science and commerce by actively reconstituting the meanings of commercialization better to fit with their self-endorsed values and professional goals. This amounts to what El-Sawad et al (2004) refer to as a 'double think' strategy for alleviating any psychological discomfort generated from holding contradictory norms.

6.3. The Entrepreneurial Scientists as 'Committed' Commercializers: the 'Gold' and 'Puzzle'

The survey results show that the type IV entrepreneurial scientists set themselves apart from the other two categories by the apparent importance of the 'gold' as a motivating factor. In the interviews, these scientists also openly acknowledged the relevance of financial rewards. The following remark made by a company founder is 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...*' (Type IV professor, computer science). It would appear that these scientists have been captured by the 'for-profit' motive. However, probing deeper into their seemingly 'self-interested' economic narratives suggests a more nuanced and ambivalent picture. In the interviews, these scientists sought to reframe what money meant for them to legitimate their engagement in 'profit making' activities. Some talked about the money reward in a somewhat negative manner in that it was portrayed as a source of discontent, what Herzberg (1966) refers to as a 'hygiene' factor, rather than a positive motivator. Complaints about being underpaid and lagging academic salaries permeated the conversations in the interviews when the scientists responded to the question about the money incentive. The same company founder quoted above said, '… *the university pays absolute peanuts and therefore you'd be totally mad not to do it if you are in an area where you can do it*'.

Academic scientists, like everyone else, need to earn a decent living. Some may well be 'cashing in' on their scientific expertise. Given that money is not supposed to be the 'ideal typical motivation' in academia, the relevance of the gold could have been under-reported in the survey. The evidence from the interviews suggests that this 'social desirability bias' (Moorman and Podsakoff, 1992) may have affected the responses of those scientists who identify more closely with the traditional academic norms than the Type IV scientists. For example, the Type II and III scientists were less at ease in talking about the money incentive in the interviews. Some tried to downplay its personal importance by using humour or laughter during the conversation, saying that the extra income could help to '*pay children's school fees*' or '*to cover the mortgage*'. Several tried to distance themselves by placing the 'blame' on their wives. For example, one company founder said that money was '*less important*' for himself, '*but if you ask my wife, she might give you a different answer*!' (Type III professor, physics). Humour, according to Coser (1966), is a form of role distance which can be used to allay feelings of discomfort.

However, what is clear from the evidence presented is that even for the apparently most market-oriented Type IV scientists, the gold appears to be only one of the motivational drivers underlying their commercial endeavours. Though not captured in the survey results, the interviews reveal the salience of an enjoyment-based (hedonic) intrinsic motivation (Lindenberg, 2001) among the entrepreneurial scientists. For example, many used words such as 'excitement', 'fun' and 'thrill' to describe the psychic satisfaction derived from taking part in commercial ventures. To some, the sense of achievement that they experienced in starting up a business venture was no less intense than the satisfaction of solving a scientific puzzle. The following interview quote vividly expresses this affective psychological state experienced by a company founder: '*….Curiosity, fantasy and excitement…The major reward for me is the excitement. The excitement of doing it, number one; number two, the intellectual satisfaction of seeing your ideas going all the way through to make medicines that will change human suffering. So emotional, and then taking part in an organisation, it's a fantastic organisation!*' (Professor, biomedicine). Another Type IV professor stated that it was '*ambition*' and his '*overwhelming ego*' that drove his commercial ventures.

The Type IV entrepreneurial scientists are 'committed' commercializers who appear to be driven by what Shane et al (2003) refer to as an 'egoistic passion' for achievement. This manifests in their love for the activity as well as the fortune that may come along with it. They have autonomous reasons for pursuing the puzzle as well as the gold, and external regulation may have limited effect on their behaviour.

7. CONCLUSION AND IMPLICATIONS

The assumption that scientists are motivated by the ribbon and puzzle in academic research while commercial engagement is driven primarily by the pursuit of the gold builds on a false dichotomy and polarised view of human motivation. Drawing on theories of motivation in social psychology, this study offers important insights into the diverse motives driving the commercial behaviours of scientists. In common with several other studies (e.g. Baldini et al., 2007; Göktepe-Hulten and Mahagaonkar, 2010), it finds that the great majority of the scientists are motivated by the traditional rewards of the ribbon in their commercial pursuits and the gold is seen as important only by a small minority. Beyond the ribbon and gold, this study highlights the role of intrinsic motivation, as in puzzle-solving, in driving the commercial endeavours of many of the scientists studied. Intrinsic motivation has long been recognised by social psychologists as a pervasive and powerful driver of human action but is neglected in much of the existing research on scientists' transition to academic entrepreneurialism. This study suggests that a fuller explanation of scientists' commercial behaviour will need to consider a broader mix of motives beyond the narrow confines of extrinsic rewards to include the social and affective aspects related to intrinsic motivation. Scientists, like other professionals, have the desire to expend effort to benefit others and society in the context of both academic and entrepreneurial science. This 'pro-social' motivation is a specific form of intrinsic motivation (Grant, 2008). Moreover, having fun or the joy of achievement is at the heart of Lindenberg's (2001) idea of 'enjoyment-based' intrinsic motivation. The idea that fun of play is an important motivation underpinning creative and inventive behaviour is a longstanding one (Rossman, 1931; Loewenstein, 1994). Gustin (1973) argues that creative scientists are motivated to do charismatic things and that science is charismatic because of its puzzle-solving nature. One might argue that for some scientists, commercial engagement represents a kind of puzzle that satisfies their desire for pursuing 'charismatic' activities.

This study has also provided a close analysis of how scientists' value preferences influence their motives for commercial engagement and the relative importance of the 'gold', 'ribbon' or 'puzzle' as desired outcomes. The identification of three distinct orientational categories among the scientists engaged in commercial activities suggests that there is no one single type of entrepreneurial scientists driven by a common motive. Although previous research suggests that scientists involved in commercialization are heterogeneous (Shinn and Lamy, 2006; Markman et al., 2008), this study attempts to provide a first theoretical explanation. It shows how motives for behaviour vary in accordance with the level of congruence between individuals' values and those associated with the activity concerned. The analysis draws attention to 'internalisation' of values and external regulation as a key factor differentiating the types of motives driving the commercial behaviour of scientists. Values are not fixed but may evolve over time which could result in changes in motives and behaviours. Although the data presented in this paper relate to a single point in time and therefore do not provide direct evidence of change, the differently positioned scientists on the self-determination continuum illustrates the possibility of orientational shifts. SDT argues that human beings have an organismic tendency towards autonomy and self-regulation in their behaviour. However, this by no means suggests that an introjected behaviour will gradually become identified or integrated over time. Evidence from the interviews shows the indeterminacy of the 'traditionalists'. The preponderance of the 'hybrid' category illustrates that normative change, more often than not, involves the paradoxical combination of opposing values in an ambivalent manner. The salience of enjoyment-based intrinsic motivation among the 'entrepreneurial' scientists illustrates the primacy of self-motivation rather than external regulation in driving their commercial behaviour.

The findings of this study also offer some practical implications. Policies designed to promote research commercialization often assume that academics respond to financial incentives tied to successful exploitation of their ideas. However, if academics are motivated by a complex mix of extrinsic and intrinsic rewards, then policy initiatives focussing narrowly on providing financial rewards might be inadequate or even misplaced. Moreover, given the diverse values and motives underlying scientists' commercial pursuits, it is unlikely that an undifferentiated approach will be effective in eliciting the requisite effort across the board. Some authors (Hoye and Pries, 2009; Krabel and Mueller, 2009) propose that policies to facilitate academic entrepreneurialism should target the subpopulation of academic researchers with commercialization-friendly attitudes such as the 'habitual entrepreneurs'. This study suggests that external regulation may have limited effect on those who are already deeply engaged in the activity as in the case of the Type IV entrepreneurial scientists. These scientists have autonomous reasons for pursuing commercial science and they may follow what they find to be professionally challenging and personally interesting rather than anything else. On the contrary, this study suggests that it is the Type II traditionalists who may be most amenable to behavioural change in response to external rewards linked to the ribbon. In particular, rewards in the form of additional funding for research and ascription of academic status to commercial success may have high motivating power for inducing some traditionalists to go down the commercial path. These ribbon-related rewards may also reinforce the commercial behaviour of the Type III hybrids and strengthen their perception of the positive benefits of the activity. There is, however, always a potential danger that top-down engineering of entrepreneurialism may undermine scientists' sense of self-determination and the intrinsic, puzzle-solving aspect of their motivation which is the ultimate driver of creativity. While intrinsic motivation cannot be enforced, it can be enabled through socialisation and competence enhancing provisions to strengthen feelings of autonomy and the culture of creativity and pro-social motivation (Osterloh, 2006).

Before closing, a number of limitations of the study should be noted. First, the items used to assess motivation were derived initially from the individual interviews and built on the conceptual literature on different aspects of motivation. Although the consistency between the interview and survey findings demonstrates reliability of the measures adopted, more use could have been made of the motivational scales developed by social psychologists to incorporate the enjoyment aspect of intrinsic motivation[6]. Second, the study has examined the relationship between the motivating factors and commercial engagement in terms of whether the scientists had been involved in any commercial activities. This addresses the issue of behavioural choice but does not offer insight into the motivational implications for behavioural intensity or persistence. The interview data offer tentative evidence about the variation in motivational strength across the three different categories of scientists and the likelihood of behavioural maintenance. Future research might include additional measures such as the amount of time spent on the activity and duration of engagement to capture behavioural intensity and persistence. Thirdly, the cross-sectional nature of the data precludes an analysis of change in motives over time. The question of how scientists might shift from one type to another over the course of their careers and possible causes merit further research. Finally, the nature of the sample also calls for some qualification. The study has looked at the experience of a small sample of 'elite scientists' in major research universities who have relatively strong bargaining power and varied resource options. Great care would be needed before extending these findings to scientists working in a more constraining environment such as Britain's 'new universities'.

Figure 1 Scientific Motivation and Commercial Engagement: A Conceptual Framework

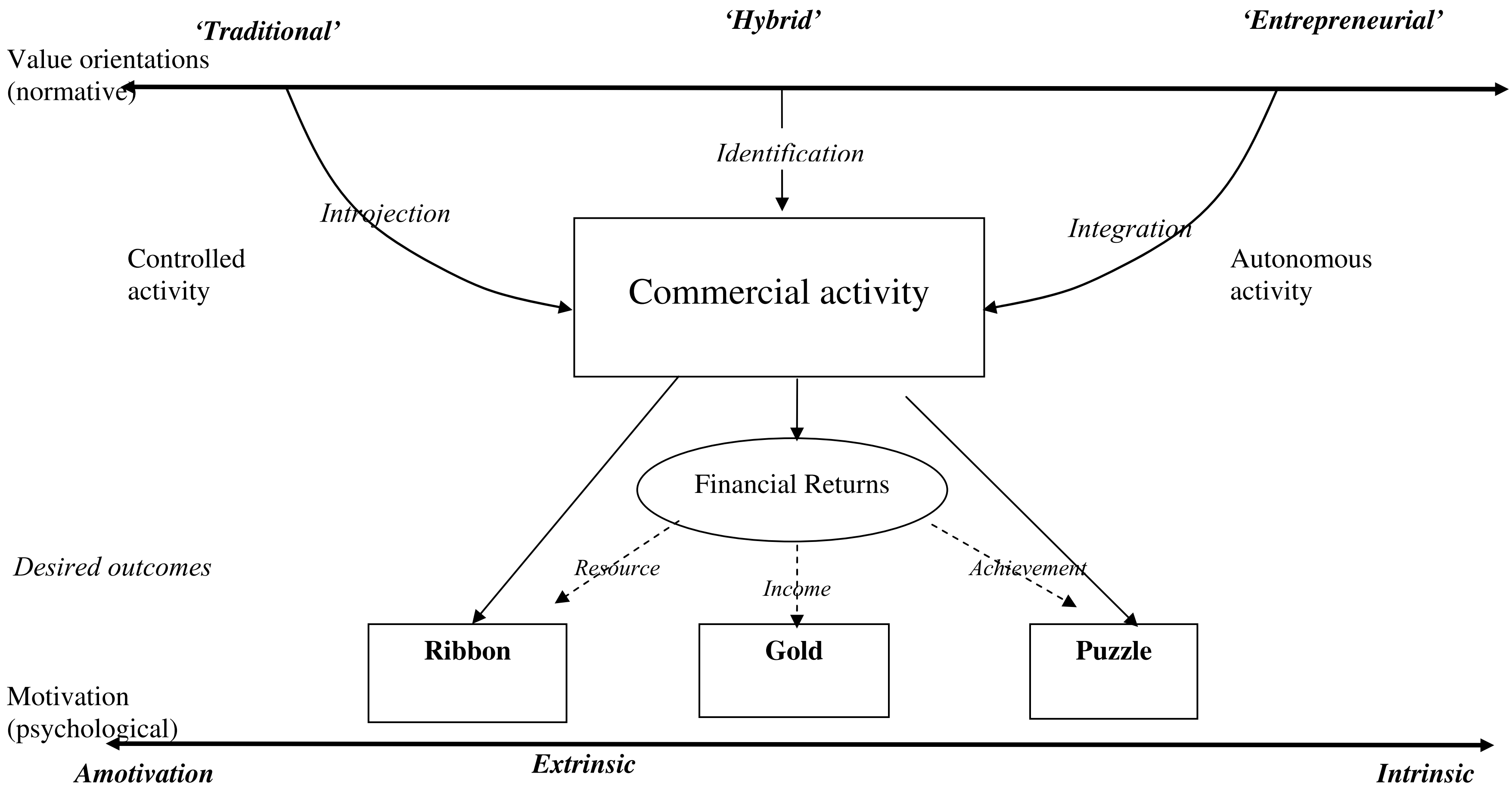

Table 1 The interview and survey samples

Discipline	No of interviewees	No. of survey responses	
Biosciences/medicine*	13	347	(21%)***
Computer science/engineering	11	174	(26%)
Physical sciences**	12	213	(25%)
Total	36	734	(24%)

*It was not possible to clearly distinguish the survey population between these two disciplines as many academics in medicine or related departments were researching in the field of biological sciences. The breakdown of responses in terms of main research areas were: biological sciences 218 and medicine 129.
** These include chemistry (58), physics (89) and mathematical sciences (66).
*** The slightly lower response rate 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 Scientists' orientations towards university-industry links

Orientational categories	Interview sample	Survey sample
Type I 'Pure traditional' **-**believes academia and industry should be distinct and pursue success strictly in academic arena	3 (8%)	110 (16%)
Type II 'Pragmatic traditional' -believes academia and industry should be distinct, but also recognises need to collaborate for pragmatic reasons	8 (22%)	230 (34%)
Type III 'Hybrid' - believes in the fundamental importance of science-business collaboration for scientific advancement, but also recognises need to maintain boundary	16 (44%)	266 (39 %)
Type IV 'Entrepreneurial' -believes in the fundamental importance of science-business collaboration for knowledge application/exploitation	9 (25%)	70 (11%)
Total (N)	36 (100%)	676 (100%)

Table 3 Value orientations of scientists and industrial engagement

	Type I Pure Traditional	*Type II Pragmatic Traditional*	*Type III Hybrid*	*Type IV Entrepreneurial*	*Total (N)*
No links	40%	30%	23%	7%	100.0% (156)
Collaborative*	12	40	42	6	100.0 (277)
Commercial**	6	30	47	17	100.0 (243)
*Of which: company affiliates/founders****	*4*	*25*	*50*	*20*	*100.0 (125)*
Total (N)	16 (*110*)	34 (*230*)	39 (*266*)	11 (*70*)	100.0 (*676*)

X2=102.15; df=6; p<0.001

*Those engaged in collaborative links only: collaborative research, contract research, consultancy, student sponsorship and joint publication.

** Those engaged in both collaborative and commercial links including patenting/licensing, affiliation with start-ups and company formation.

*** This is a subset of those with commercial links; excluded from X2 test.

Table 4 Proportion of respondents who reported the motivating factors as 'important' or 'very important'

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

	All	Collaborative	Commercial	Type I+II** 'Traditional'	Type III 'Hybrid'	Type IV 'Entrepreneurial
To increase funding and other research resources	83%	80%	86%	89%	90%	68%
Application & exploitation of research results	70	57	84	73	92	86
To create opportunities for Knowledge exchange/transfer	66	58	73	58	84	70
To satisfy your intellectual curiosity	59	57	62	52	69	60
To build personal and professional networks	59	57	61	52	68	62
To enhance the visibility of your research	48	43	52	42	60	50
To provide work placement or job opportunities for students	41	45	35	30	40	33
To increase your personal income	27	17	38	34	35	59
Number of observations (N)*	*(502)*	*(266)*	*(236)*	*(83)*	*(110)*	*(42)*

*Only those with industrial links responded to this question. The total number of observations varies slightly across the different items due to missing or 'don't know' responses.
** Only 13 out of the 110 Type I scientists were involved in commercial activities and responded to this question; these were merged with the Type II to form a single 'traditional' category.

Table 5 Factor analysis*

Motivating factors	Mean	St. Dev.	Factor 1 Reputation (*Ribbon*)	Factor 2 Knowledge (*Puzzle*)	Factor 3 Curiosity (*Puzzle*)	Factor 4 Income (*Gold*)	Factor 5 Funding (*Ribbon*)
To increase funding and other research resources	3.25	.922	.164	.120	.005	.006	**.972**
Application & exploitation of research results	2.88	1.000	.066	**.900**	.003	.138	.129
To create opportunities for Knowledge exchange/transfer	2.78	.966	.232	**.759**	.317	-.055	.013
To satisfy your intellectual curiosity	2.66	1.044	.148	.173	**.934**	.042	-.011
To build personal and professional networks	2.67	.984	**.731**	.132	.294	.231	.155
To enhance the visibility of your research**	2.37	1.050	**.451**	.427	.356	.245	.202
To provide work placement or job opportunities for students	2.22	1.028	**.900**	.132	.003	-.046	.072
To increase your personal income	1.90	1.019	.095	.079	.048	**.969**	.003
Rotation sums of squared loadings			1.66	1.65	1.19	1.08	1.03
Proportion of variance explained (%)			20.80	20.69	14.86	13.49	12.89
Cumulative proportion of variance explained (%)			20.80	41.49	56.35	69.84	82.73

* Principal Component Analysis with Varimax rotation; 5 factors are retained in the extraction.
** Although this factor loads almost equally onto factors 1 and 2, it is grouped under factor 1 ‘reputation’ for two reasons: a) it makes sense to treat ‘research visibility’ as a ribbon-related factor; and b) it loads strongly (0.618) on factor 1 when PCA is performed on the sub-sample of those engaged in commercial activities.

Table 6 Factors motivating commercial engagement

Binary logistic regression: Dependent variable=commercial engagement (1,0)

Variables	*Model 1*		*Model 2*	
Funding (*Ribbon)*	0.248*	(0.104)	0.266*	(0.113)
Reputation (*Ribbon)*	-0.314**	(0.101)	-0.328**	(0.110)
Knowledge (*Puzzle)*	0.520***	(0.105)	0.514***	(0.114)
Curiosity (*Puzzle*)	0.083	(0.101)	0.076	(0.107)
Income(*Gold)*	0.545***	(0.103)	0.571***	(0.113)
Controls				
Basic research			-0.069	(0.240)
Biosciences			0.802*	(0.355)
Medicine			0.959*	(0.387)
Computer Sci/Engineering			0.707*	(0.344)
Chemistry			0.855*	(0.418)
Professor			0.365	(0.239)
Age (<40)			-0.852***	(0.268)
Previous industrial experience			0.318	(0.232)
Constant	-0.108	(0.100)	-0.812*	(0.348)
Cox & Snell R Square	0.135		0.189	
Nagelkerke R square	0.180		0.253	
Model chi square	67.851		96.417	
Significance	0.000		0.000	
Classification correct	63.9%		69.7%	
N=468				

+p<0.1 *p<0.05 **p<0.01 ***p<0.001

Notes: a) Robust standard errors in brackets

b)The reference category for the disciplinary variables is Physical sciences (physics and mathematics).

Table 7 T-tests for equality of means of factors motivating commercial engagement: traditional, hybrid and entrepreneurial

Motivating factors/ Orientational categories	***Traditional*** (N=79)		***Hybrid*** (N=105)		***Entrepreneurial*** (N=38)		**Anova f-test**	**Two sample t-tests**		
	Mean *X*	Std Dev.	Mean *Y*	Std Dev.	Mean *Z*	Std Dev.	Between 3 groups	Traditional vs. Entrepreneurial *X≠Z*	Traditional vs. Hybrid *X≠Y*	Hybrid vs. Entrepreneurial *Y≠Z*
Funding	0.29	0.86	0.16	0.85	-0.41	1.03	8.506 ***	3.898 ***	1.061	3.364 ***
Reputation	-0.26	0.98	-0.39	0.99	-0.19	0.95	1.200	-0.343	-1.502	0.835
Knowledge	-0.05	0.94	0.43	0.73	0.26	0.99	7.140 ***	-1.638 +	-3.916 ***	1.123
Curiosity	-0.18	0.95	0.17	0.89	0.09	0.99	3.224 *	-1.446	-2.530 **	0.413
Income	0.16	1.02	0.14	0.99	0.84	1.01	7.258 ***	-3.370 ***	0.084	-3.639 ***

+p<0.1 *p<0.05 **p<0.01 ***p<0.001

Appendix

Table A1 Scientists' orientations towards academia-industry collaboration: Distribution of responses by first and second best choices

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	( )	( )

Orientational category	Choice of statements	Distribution by first choice No. (%)	Distribution by second choice No. (%)
Type I 'Pure Traditional'	1	110 (16%)	87 (13%)
Type II 'Pragmatic Traditional'	2	230 (34%)	203 (30%)
Type III 'Hybrid'	3	266 (39%)	213 (32%)
Type IV 'Entrepreneurial'	4	70 (11%)	142 (21%)
	Multiple* answers	-	31 (4%)
Total		676 (100%)	676 (100%)

*No answer or multiple (unclassifiable) answers to first choice are excluded from the analysis: 58 cases

Table A2 Descriptive Statistics

	Min.	Max.	Mean	Std. dev
Funding	-2.591	1.407	0.012	1.00
Reputation	-2.153	2.222	-0.002	1.00
Knowledge	-2.797	1.871	0.007	1.00
Curiosity	-2.361	1.991	-0.002	1.00
Income	-1.569	2.636	0.007	1.00
Basic research	0	1	0.44	0.50
Biosciences	0	1	0.27	0.44
Medicine	0	1	0.18	0.39
Comp/Eng.	0	1	0.28	0.45
Chemistry			0.10	0.30
Physical Sci. (ref.)	0	1	0.17	0.37
Professor	0	1	0.39	0.49
Age1 (<40)	0	1	0.27	0.44
Previous experience	0	1	0.38	0.49

Table A3 Correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Funding	1													
2. Reputation	.000	1												
3. Knowledge	-.020	-.003	1											
4. Curiosity	-.002	-.008	-.007	1										
5. Income	-.002	-.001	-.003	.000	1									
6. Basic research	-.111*	-.049	-.181**	-.071	-.138*	1								
7. Biosciences	-.097*	-.064	-.101*	-.131**	-.074	.351**	1							
8. Medicine	.077	-.165**	.009	.043	-.073	-.252**	-.287**	1						
9. Computer sci/engineering	.026	.167**	.142**	-.012	.202**	-.185**	-.378**	-.298**	1					
10. Chemistry	.134**	.084	-.010	.075	-.081	-.023	-.203**	-.160**	-.211**	1				
11. Physical sci. (ref)	-.115*	-.031	-.057	.060	-.017	.085	-.269**	-.212**	-.279**	-.150**	1			
12. Professor	.000	-.023	-.010	.021	.014	.115**	-.055	.001	.013	-.043	.084	1		
13. Age (< 40)	.070	.097*	-.036	-.035	.071	.010	-.065	-.066	.099*	.052	-.016	-.401**	1	
14. Previous experience	.007	.078	.121**	.085	.209**	-.145**	-.159**	-.220**	.272**	.021	.072	-.004	-.026	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

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[1] Thorough searches were conducted on the universities' websites and the individual names, their departmental affiliations and e-mail addresses were obtained based on the information available. In the great majority of the cases, we were able to obtain the full lists of academic staff of the relevant disciplines. There were a very small number of exceptions in the case of bio-medical research where the staff names were withheld because of the sensitivity of the work. In the case of research units, we included all the centre directors and principal investigators listed but excluded the post-doctoral researchers and graduate students the majority of whom were contract researchers.

[2] The 'commercial' category includes those engaged in both collaborative and commercial activities, as well as a small minority (1.9%; 14 respondents) engaged in commercial activities only.

[3] Following Mallon et al (2005), the term 'orientational category' is used here to refer to an aggregation of individual data which classify people according to their individual predispositions based on their beliefs, wants and plans. It reflects differences in value preferences and subjective interpretations of actions.

[4] In a survey of this kind, it is possible that individuals may exaggerate motives that they believe are socially desirable and give lower scores to items deemed less socially desirable. The data on motives should be interpreted bearing in mind the possibility of such a 'social desirability bias' (Moorman and Podsakoff 1992).

[5] Chemistry was initially included in the category of 'physical sciences' in the sample shown in Table I but treated as a separate discipline in the regression because the descriptive cross-tabulation results show some significant variations in the attitudes and industrial activities between the scientists in this field and those in physics and mathematics.

[6] For example, the Work Preference Inventory (Amabile et al 1994) and the Intrinsic Motivation Inventory http://www.psych.rochester.edu/SDT/measures/word/IMIfull.doc