Women's involvement in technology transfer activities from physics and engineering departments within the UK universities

A pilot study conducted by the Institute for Entrepreneurship on behalf of the Institute of Physics

Professor Elizabeth Chell, Mine Karatas-Ozkan, Dr Rosie Read and Laura Wilson*

Institute for Entrepreneurship, University of Southampton
Building 25, Highfield, Southampton, SO17 1BJ
Tel: 02380 5918960
Fax: 02380 5918981
E-mail: e.chell@soton.ac.uk

*Portsmouth Business School, University of Portsmouth

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1. Introduction

The purpose of this pilot study is to explore the extent and process of women's involvement in science and technology transfer activities from Physics, Physics-related, and Engineering departments within the UK universities. By 'technology transfer' is meant the application of scientific knowledge with a view to developing a new product or process of commercial value by means of business creation, licensing or early stage prototyping of an innovation (Chell, 2002).

Women are under-represented in nearly all areas of science and technology transfer endeavours and indeed there has been a dearth of research that investigates the extent and process of engagement by women in technology transfer. Taking this gap in our knowledge as the focus of this preliminary investigation, we have taken a critical approach, that is, to ensure that we examine whether 'gender' is the issue and to attempt to get a more rounded view of why university-based scientists might engage in technology transfer activities at all. Engagement in technology transfer is viewed as a complex phenomenon, which is a function of the interrelated factors such as attitudes towards business start-up, social norms and perceived feasibility that influence their motivation and intention to engage in technology transfer. It should also be noted that these activities are embedded in certain socio-cultural milieu that needs to be explored.

The pilot study consisted of two parts. Part 1 of the study sought to find some quantitative evidence that might differentiate male and female scientists' approach to their career, and in particular their possible engagement in tech transfer. Whilst there are subtleties and differences in engagement in technology transfer, the nature of a focused quantitative survey does not necessarily allow one to explore these subtleties. We have therefore designed the second part of our study, Part 2, as a qualitative survey where we carried out two focus groups and a number of qualitative interviews that enabled us to delve into underlying motivations so that

we have both a detailed understanding and the ability to explain our albeit preliminary findings.

The report is structured as follows: First, the research aims and questions are outlined in greater detail. Second, the literature review is presented by critically evaluating the academic and governmental debates on women and Science, Engineering and Technology (SET) education and entrepreneurship. Third, the methodology of the study is delineated with a focus on the overarching theoretical framework entitled 'Theory of Planned Behaviour', which underpins the research design. Fourth, the findings from the quantitative survey (Part 1) are presented followed by a discussion on findings from the qualitative survey (Part 2). The report concludes with some interesting and encouraging conclusions.

2. Research aims and questions

The Institute of Physics seeks to improve the understanding of female involvement in physics and engineering education and employment in general and women physicists' experience of university-based entrepreneurship in particular. Therefore, the overall aim of the research is to generate insights into the incidence of female technology transfer activity in physics and physics related disciplines, mainly engineering, in higher education institutions in the UK. Part 1 of this pilot study aims:

- To identify whether there are gender differences in the intentions of physicists and engineers to engage in technology transfer,

- To investigate any gender differences in attitude towards technology transfer

- To examine whether there are any gender differences in belief toward the pursuit of a career in small business development through technology transfer

- To investigate whether there are significant contextual factors that affect attitude toward, and beliefs about, the pursuit of enterprise activities.

- To investigate whether there are any person-specific factors that affect the pursuit of an enterprising career.

Part 2 of this pilot study aims to consider the following issues:

- To understand the process of technology transfer as experienced by women physicists (i.e. how an idea with potential for technology transfer is identified, developed and moved into incubation),

- To identify whether there are any gender differences in the process.

We take as our starting assumption that there will be fewer female students attending physics and engineering courses in HEIs in the UK, as indeed is supported by the HESA statistics (HESA, 2004). The question then becomes, given that this is a self-selected group, are there any gender differences in intention, attitude and belief toward the pursuit of technology transfer activities, including business founding?

The translation of these objectives to research questions in the Part 1 of this pilot study is as follows:

- Is there a difference in attitude and belief about technology transfer activities between male and female physicists?
- Is there any evidence to suggest that women are more reticent in their attitude towards an enterprising career?

- What are the more favoured career choices of male and female physicists and engineers? Are there significant differences in choice by gender and/or differences by subject/discipline?
- Does the selected career choice map on to intention to engage in enterprise activity? (Where 'enterprise activity' includes technology transfer and/or business founding).
- Are there any measurable cultural factors that might influence physicists' orientation towards technology transfer activity and an enterprising career?
- Are there any person-specific factors such as age that might influence physicists' orientation towards technology transfer activity and an enterprising career?
- What kind, if any, pressure from significant others do physicists/engineers experience in making career choices, including that of engaging in enterprise activity?

The Part 2 addresses the following questions:

- What is the nature of the process of technology transfer as experienced by female and male physicists and engineers (i.e. how is an idea with potential for technology transfer identified, developed and moved into incubation)?

- Are there any gender differences in the process?

3. Literature review

The areas we address in this literature review section of the report include gender and SET qualifications and employment, women and SET interventions, women and entrepreneurship, SET entrepreneurship and finally gender and SET entrepreneurship in their respective order.

3.1 Gender and science, engineering and technology (SET) qualifications and employment

The complex and historically embedded nature of women's under-representation in science, engineering and technology education and employment is highlighted by a number of scholars (Siann and Callaghan, 2001, Bebbington, 2002, Glover, 2002; Chell, 2002). Women occupy two percent or less of professorial posts in many of the science, engineering and technology-based (SET) sub-disciplines (Bebbington, 2002).

Physics as a single discipline is still seen by many as a historically male-dominated profession to which women have only relatively recently been admitted, for example see Clay (1982), Camporesi (2000) and Costas (2002) and yet they are under-represented. In search of explanations for the persistent phenomenon of women's under-representation in academic employment in Physics, the subject is studied along various dimensions, for example, entry opportunities; promotion; pay; retention issues; fixed-term contract issues (Bagilhole, 2000).

In examining under-representation, patterns of vertical and horizontal segregation are observed: The pattern of attrition (the further one goes up the hierarchy, the fewer the women) persist in all disciplines including business, social studies and language-based studies, not just SET. However, inter-disciplinary differences are both evident and noteworthy; women are best represented in language-based studies at almost every grade and worst represented in engineering and technology (Bebbington, 2002b, Ackers, 2001). Biosciences are not so male-dominated, but again marked attrition is notable: more women are gaining PhDs in the biosciences but they still represent only 9% of professorial appointments (Bebbington, 2002b). Engineering provides a strong contrast with biology: women are heavily under-represented at undergraduate level as subsequently within engineering

employment. A report by the European Technology Assessment Network (ETAN, 2000) on women and science shows a pattern replicated across Europe of generally higher representation of women in the social and biological sciences and lower presence in the natural sciences and engineering. This pattern is also seen in North America, thus this is not a UK-specific issue. Rather, overall it suggests perhaps issues of structures and the cultural representation of SET education and careers. Further, Glover (2000) argues that it is physics, not other sciences that have remained obdurately male, thus this discipline either has additional structural or cultural issues in comparison with other disciplines, or it exists at one extreme of an existing set of problems or barriers.

In terms of representation in SET careers, there are also clear ethnic variations. Of note is under-representation of African-Caribbean people in scientific employment (Bebbington, 2002a) and over-representation of Indian, Bangladeshi and Chinese students on science undergraduate courses (Baker, 2002). These findings tend to strengthen a hypothesis that the issue is the cultural representation of SET subjects and their attraction to different segments of society, rather than issues of direct discrimination against particular minority groups or against women. Bebbington's (2002b) study usefully comments that the literature on women in SET does not address how women's experiences of scientific careers vary according to their individual differences, including their ethnicity or class backgrounds. Glover (2002) also argues that women's progress in scientific employment must be considered in terms of four distinct phases: qualifying, translating scientific qualifications into scientific employment, persistence and advancement. Other research has further considered the ways in which gender discrimination is embedded within organisational cultural practices, for example, Bagilhole and Woodward (1995) note sexual harassment as an under-recognised phenomenon in the UK academic profession and link the issue with academic culture.

Bebbington (2002b) attempts to explain the problem of under-representation using a domestic responsibilities model: the demands of motherhood and the family. Morley (2002) questions the appropriateness of this model as an explanatory framework: Her critique centres on the notion that the model positions women in "normed" relationships in terms of the family, implying that all women share a commonality of life-style, that unmarried or childfree women do not have responsibilities in the private sphere, and that women have restricted mobility and are in fixed situations from which they cannot easily escape. Blackwell's (2002) study, however, confirms the anecdotal evidence that women in SET occupations have difficulty in reconciling the competing demands of professional and family life. Her analysis shows that women in science and technology occupations tend to have children later in life than those in other occupations. She suggests such family formation patterns reflect the institutional contexts in which women with SET qualifications study and work.

The 'barriers model' attempts to decipher the issue of under-representation by raising the significance of a number of inter-related aspects (Siann and Callaghan, 2001): The first one is the nature of SET within secondary education. Gender patterns are observed in the choice of subjects and options. Related to this is a further dimension, which is the notion of women being deterred by the nature of scientific enquiry. Feminist scholars have argued that because scientific enquiry has, until very recently, been conducted by men, the most fundamental aspects of systematic theory in the natural sciences have been pervaded by masculine perspectives deriving from masculine experiences (Siann and Callaghan, 2001). This feminist critique of scientific enquiry contends that a 'cognitive authority' has been granted to science, which places it as pre-eminent in human thought and epistemology because of its objectivity (Harding, 1986). The counter argument is that the practice of science like any other branch of human endeavour cannot be removed from the values systems and implicit biases and ideologies of its practitioners (Siann and Callaghan, 2001).

The contention that there is a masculine culture within SET subjects is a further aspect of the under-representation of women. Cockburn (1991) and Cockburn and Ormrod (1993) have argued that the salient characteristics of SET culture are the intertwining of masculinity and technology so that technical competence has come to constitute an integral part of masculine gender identity and a particular kind of masculinity has become central to the working practices of technology. This issue is reinforced when one considers the extent to which the great majority of professions have been dominated by patriarchal discourses and practices.

A fourth aspect that Siann and Callaghan (2001) highlight is the image of the scientist. Stereotypes of women scientists act as a deterrent to girls' participation in SET: inverted, somewhat socially withdrawn etc. It is worth noting that such negative stereotypes are also associated with men scientists. Therefore, the validity of this argument is rather dubious. However, the 'bearded man in a white coat' still tends to be the image conjured up by the notion of a 'scientist' (Glover, op cit).

The lack of role models and female networks in SET is suggested as the most significant obstacle to women's involvement in science cited by Siann and Callaghan (2001). Most of these problems are taken up by the recent Government document (SET Fair Report, 2002) as will be discussed in section 3. 2. It is worth noting that existence or non-existence of positive role models is only one variable in a complex dynamic that includes personal, familial and societal attitudes along with the establishment of social norms and behavioural controls that surround women scientists' participation in SET education and entrepreneurship.

Siann and Callaghan (2001) take a critical stance toward the many interventionist programmes based on tackling barriers to increasing women's participation in SET. They put forward the idea of 'choices model': contending that women's under-representation in SET should be considered not in the context of those barriers which operate to exclude them, but rather in the context of the attractions offered to women as alternative career choices. Further they explain that the

choice of a particular career is an active rejection of certain alternatives in favour of those that optimize not only interest, but also power and prestige and so locating women's under-representation in SET within the continuing gendered choice of careers is problematic. Rather, they set out some positive reasons why women entering HE may actively choose an alternative to SET as follows:

- human interest
- pay
- employment prospects
- status and image

Thus, a career track that draws women because it resonates with their value systems, is well-paid in relation to qualifications achieved, offers flexibility and perhaps stability over the longer term and attracts peer acknowledgement in terms of status and image is one that might increase women's participation in SET. However, we additionally posit that such a career track might very well appeal to larger numbers of men too.

Henningsen and Hojgaard (2002) describe the attrition of females in physics, chemistry and medicine in Denmark simply as a "leaky pipeline", finding no single cause but rather multiple cultural and social issues as well as individual institutional mechanisms and wider academic systems that do little to encourage and support the retention of women academics. Warwick University, Institute for Employment Research, found similar evidence in the UK in their report for the DTI "Maximising Returns to Science, Engineering and Technology Careers" (2002). Fox and Stephan (2001), in a survey of 3800 SET students in North America, found gender differences in 'conditioned expectations' relating to future career paths.

The significant questions, therefore, are to what extent career paths are influenced by persistent cultural attitudes and individual expectations based on pervasive

social stereotypes, and the ways in which scientific knowledge may be gendered? According to Fielding and Glover (1999), the problem of women's under-representation in academic science requires clear delineation, recognising that career trajectories are likely to vary markedly between the scientific disciplines. Serious attention needs to be paid too, to the point that individuals experience the academic labour market in a variety of ways on account of differences in circumstance, perception, motivation and aspiration.

3.2 Women and SET interventions

A number of policy developments, as noted by Fielding and Glover (1999), have been seeking to address these issues and increase the representation of girls and women in scientific education and employment through a series of reports since late 1960s, which are listed in the following Table 3.1. The more recent policy documents include: The Rising Tide (1994) Report, which brought about the foundation of the Office of Science and Technology (OST)'s Promoting SET for Women (PSETW) Unit in 1995. The Unit is very instrumental in supporting the dissemination of 'A Guide to Good Practice for HEIs' developed by the Athena project (DTI, 2003b).

Table 3.1 Policy documents pertaining to women and SET education and employment

Title of the document	Publication year
The Dainton Report	1968
The Finniston Report	1980
Realising Our Potential	1993
The Rising Tide	1994
Forward Look	1996
SET Fair Report	2002
Maximising Returns	2002
Government's Response to SET Fair	2003

SET Fair Report (2002) identifies and reinforces existing knowledge about the key problems that women perceive in respect of the pursuit of careers in science and

technology. They include: a lack of transparency for pay and promotion procedures; gender imbalance in the decision-making process; poor understanding of scientific employment cultures; slow setting up and take-up of work life balance policies; intangible cultural factors that appear to exclude women from the corridors of power; institutional sexism; stereotyping of careers advice; lack of knowledge and experience for girls and young women in non-traditional areas of work; the problem of offering short term contracts to career research scientists; the linear progression of research based careers based on cumulative publications performance indicators; the associated problem of a career break or a partner relocating; ingrained conservatism towards women's assumption of the same level of responsibility relative to their male counterparts; informal practices including rumour, gossip, sarcasm etc. encoded in the organisational culture.

SET Fair Report (2002) offers a strategic approach to tackle the above type of issues where it is believed that the intervention is necessary to: (a) reduce fragmentation of efforts and enable all stakeholders to play an active and effective part in change; (b) help employers to deliver a change in culture, supporting individual women scientists, engineers, and the organisations, who help to manage the skills and workforce for each sector; and, (c) to stimulate organisational implementation to create an inclusive, modern working environment. To this end, The SET Fair report (2002) structures the recommendations (the agenda for action), in the form of a pyramid of measures at three levels (i.e. individual, employers and policy makers) to tackle the cultural change needed to increase the retention and advancement of women across SET employment.

Clearly changing the culture is a necessary step, but there is not much in the SET Fair report on changing the perceptions and attitudes of men working in SET. Changing the culture and destroying the stereotypes of both men and women in SET is both very crucial and difficult. As stated in the IoP's response to the Report, the traditional academic research culture, involving long and intense hours

of work in the laboratory or the industrial environment, where frequent site or overseas visits at short notice are the prevailing norms,

are not supportive to women, but neither are they positive for men with families and other commitments.

A further issue, which has not been tackled well in the SET Report, is the retention and development of the female SET staff in both large and small organisations. The problem is far greater than the entry to the SET employment market issue. It is also establishing a career on equal and fair grounds. Understanding the implications of female staff retention and development to the business processes and yet well-being of the organisations is fundamental. The Report does not suggest any real measures to address these issues. On the other hand, the haemorrhaging of both male and female scientists from HEIs and industry suggests the need for both types of organisation to address the issue of staff retention.

The adverse impact of Research Assessment Exercise (RAE) on recruitment patterns of female scientists is an increasingly critical concern. Since the RAE is so fundamental to the international profile of a science department, new appointments tend to be offered to people that have an established track record. As mentioned in the IoP's response to the Report, in Physics a recent survey shows that the average age of appointment to lectureship posts is 35. Therefore, in order to be appointed, a candidate must both have an excellent academic record and also be mobile – a concern for women, in particular, attempting to balance their family and work commitments.

The most recent Government initiative is the establishment of 'the UK Resource Centre for Women in Science Engineering Technology' (UKRC). The SET Fair Report initially proposed a 'Working Science Centre' to bring together the stakeholder groups and enable them to tackle the issue of increasing the number of women in SET. Later, it was decided that it should be called 'a Resource Centre' to embrace a more comprehensive dynamic resource centre idea for all

women in SET. It was officially launched on the 16th of September, 2004. The built environment is based in Bradford and is being developed by the JIVE consortium of Bradford College, Sheffield Hallam, Open and Cambridge Universities. The UKRC is funded by the DTI for three years (2004-2007)[1]. The mission of the Centre is stated as establishing a dynamic central hub that provides accessible, high quality information and advisory services to employers, (including academia and the research councils), professional bodies, Sector Skills Councils, careers professionals and Higher and Further Education to promote best practice in the recruitment, retention and progression of women in SET. The Centre will map, coordinate and build on the range of good practice initiatives that have already been developed in this field by providing a strategic focus for driving forward the UK women and SET agenda.

3.3 Women and entrepreneurship

The current Government objective for women's participation in enterprise is *"to increase significantly the numbers of women starting and growing businesses in the UK, to proportionately match or exceed the levels achieved in the USA"* (The SBS, 2003: 4). USA female entrepreneurship rates stand at 28 per cent majority female-owned firms, compared with *"12-14%"* in the UK (SBS, 2003: 6). The UK, therefore, aims to eventually double its female entrepreneurship rate, albeit over an unspecified timeframe. Recent policy interventions include the publication of a broad policy statement document, *A Strategic Framework for Women's Enterprise, Sharing the vision: a collaborative approach to increasing female entrepreneurship* (SBS, 2003). This document charges RDAs and Business Links with the task of better co-ordinating and understanding the needs of women, would-be and existing, entrepreneurs. However, policy as outlined in the *Strategic Framework for Women's Enterprise* indicates no specific measures for women with a SET background. That such women may experience particular challenges, different from men and other women, is simply not acknowledged in policy

[1] The official website of the UKRC is www.setwomenresource.org.uk.

background documents or in recommendations (see, also Chell, 2002). Instead, the focus of current policy is very much on social inclusion and the needs of women with children, with a surprisingly strong emphasis on fostering childcare enterprises as a business option for women with children. The final version of the *Lambert Review of Business-University Collaboration* (2003) makes a number of references to women but consistently refers to actions and interventions outlined in the *Strategic Framework*, which are not particularly relevant to women academics.

In order to more fully understand the context in which all would-be female entrepreneurs are situated, it is useful to examine the participation rates of women in entrepreneurship generally, and to describe common barriers and choices that women face. Building on such examination, areas of particular concern to women in an academic context and their involvement in enterprise development through technology transfer activities can be better explained. The remaining discussion is fashioned by these considerations.

3. 3. 1 Women and Entrepreneurship Participation Rates

The relatively low participation of women in business compared to men in the UK is a recurring issue in the literature (Carter et al., 2001). However, official government statistics on small firms (such as company registration, VAT registration and de-registration data) that might provide a clearer picture of women's participation are not generally disaggregated by gender in this country. Perhaps as a consequence of a lack of government push, gender statistics and data are not routinely collated by others. For example, Wright *et al's UK University Commercialisation Survey* (2002) could easily have asked for gender as a variable in their survey of 120 HEI's but did not, thus we do not have, readily available, data on women's participation relative to men in HE commercialisation activity.

In examining the statistics, women account for about 27 per cent of the self-employed in the UK as a whole (SBS, 2003). A more recent analysis of labour force data, however, shows an increase in self-employment by both sexes, showing

that 31 per cent of one million people that had started a business since 2000 were women (SBS, 2004). The participation rates for women in the UK appear to be quite typical though, of female entrepreneurship rates in most advanced economies, and certainly on a par with Northern European nations. For example, one study in examining *Global Entrepreneurship Monitor* (GEM) data across nations suggests that *"in most countries"* women's participation rates were typically around one half of that of men (Galloway *et al,* 2003), but a recent bank survey in the UK suggests that in the UK, men are *more* than twice as likely to be in the process of starting a business (Barclays Bank, 2003). One problem in this area is that data gathering methods and presentation of statistics are inconsistent because of the number of different agencies that have an interest in this area. It is noteworthy too, that official statistics may underestimate the participation of women in business; for example, women may participate through involvement as partners, or in family businesses as employees, but remain 'hidden' in official statistics. For example, a recent study for the Federation of Small Businesses (FSB, 2004) confirms higher rates of women's participation with mixed gender ownership amongst their membership in the UK, at 35 per cent. The same study indicated that the proportion of businesses wholly-owned by women was, on average, only 15 per cent in the UK. Women are therefore potentially participating in business ownership nationally at 50 per cent. The FSB study confirms an increasing rate of business ownership of about five per cent among women from their member base, as compared with 2002 (FSB, 2002).

3. 3. 2 Barriers to Women's Enterprise Participation / Choices Women Make

As barriers to women's participation in SET education and careers have been identified, so too are barriers to women's enterprise participation under debate. The *Strategic Framework* (SBS, 2003:8) cites six general barriers to women's greater participation in entrepreneurial activity as follows:

- difficulties experienced in the transition from benefits to self-employment

- lack of appropriate business support
- low levels of confidence and self-esteem
- access to finance
- the impact of caring and domestic responsibilities
- lack of appropriate role models

In a SET and commercialisation context, the first two barriers should not apply, although women may very well perceive commercialisation support to be targeted more at male colleagues, and the survey stage of this research should be able to provide some indicative evidence of any such perceptions. In terms of self-confidence, Wilson *et al* (2004) posit that there is no reliable, robust academic research evidence that supports a view that women lack self-confidence or self-esteem in an entrepreneurship context in the UK. Deakins *et al* (2002) nevertheless consistently found this anecdotal and stylised view of women's lack of self-confidence related by practitioners, both male and female, as justification for the programming of training in this area. Within the *Strategic Framework*, lack of self-confidence appears to be allied with women articulating *"fear of failure"* as a barrier to start-up (SBS, 2003: 27). In a GEM UK report, Harding (2002: 27) claims that women do indeed appear to fear business failure more than men. However, what is also well-known is that women tend to under-report their skill levels and over-emphasise their anxieties in surveys in general in comparison with men and this has also been clearly demonstrated in an entrepreneurship context (Kourilsky and Walstad, 1998). This is not the same as lacking confidence, as it can be argued that women are simply being more honest in their assessment of their abilities and what it takes to establish a successful enterprise.

That women in many spheres of life have a greater perception of risk and are more risk averse are also well-known (see Slovic's 1999 review and recent evidence

from Hartog et al, 2002) and there is some evidence that gendered structures in society contribute to these differences in risk perception (Slovic, 1999). There is not enough evidence to support a hypothesis, however, that women's aversion to risk is also a confidence issue or a serious barrier to entrepreneurial activity, since a reverse hypothesis, that women establish businesses when they are more sure of the future success of an enterprise (Hartog et al, 2002) can be viewed as a strength and not a weakness in terms of the sustainability of new ventures. In any event, in a global context, and in controlling for sector, women's businesses in Australia do not have a higher failure rate (Watson, 2003) and, in the case of Denmark, with the exception of the wholesale trade, women's businesses survive longer than male-owned businesses (Nielsen, 2002). In this respect, if such findings could be confirmed in a UK context, training and personal development for women in the area of self-confidence building and self-esteem development is unlikely to overcome or mitigate a woman's inbuilt risk aversion or fear of failure, and it may indeed not be appropriate to do so.

Surveys and other research on women's motivations for establishing businesses in the UK, North America and Europe over time often also show marked gender differences (Richardson and Hartshorn, 1995; Alvarez and Dale Meyer, 1998; Boden, 1999a; Mallon and Cohen, 2001; Orhan and Scott, 2001; Mattis, 2002; Hughes, 2003; Fielden *et al*, 2003). Support is often found in a UK context for hypotheses explored and supported in Europe and North America, thus some similarities in start-up motivation appear to transcend local culture and economic conditions, suggesting organisational structural issues in developed Western economies. For example, many women are not attracted to the rapid growth and exit business model, preferring business ownership and development over the longer term (Cliff, 1998, Gundry and Welsch 2001). In brief, while some women do choose self-employment because they develop a positive desire to start a business or to realise a good idea, many more, appear to choose self-employment for negative reasons of dissatisfaction with organisations. Others start businesses due to reasons concerned with work-life balance, childcare and flexibility that

often link back directly to negative workplace experiences. In general, in terms of push-pull factors, in the UK and beyond, more women than men seem to choose self-employment for reasons other than to capitalise on a good idea or to make money (Mallon and Cohen, 2001; Hughes, 2003; Orhan and Scott, 2001).

Women often choose to establish businesses in order to manage both market production and domestic production, including childcare, and that they limit the growth of their enterprises because of this, is also consistently well-supported in the literature (Boden, 1999b; Hundley 2000, 2001; Bell and LaValle, 2003). Moreover, the idea that some men may also limit the growth of their businesses has tended not to be addressed (Chell and Baines, 1998). All women with children find appropriate, affordable childcare an issue to some extent, whether they wish to remain in employment or wish to start a business (Dex, 2003; Dex and Joshi, 1999). But, lack of appropriate childcare as a specific barrier to starting or growing a business, is not supported. Families prefer a hierarchy that has informal, family arrangements first, local community support second, and paid-for childcare services offered by childcare organisations almost as a last resort (Belle and La Valle, 2003). Childcare needs are much less of a barrier to women's participation in enterprise than the current female enterprise participation rates among the general population in the UK might suggest.

On a lack of role models as a barrier, women in the UK clearly establish businesses and can, and do, become involved in commercial activity, whether that is spin-out companies or licensing technology. The issue is not that such women do not exist, it is more that they are not profiled nor do they come to the attention of other women often enough, or in a way, in which women can strongly identify. Evidence exists that female scientists that do receive media attention are frequently portrayed differently from men (Shachar 2000), with a greater emphasis on their personal circumstances than on their professional outputs. Deakins *et al* (2002) found evidence that women bio-scientists deliberately do not cultivate a media profile in the same way as men. Thus, seeking alternative explanations, and taking

into account other evidence that women in the UK do not value entrepreneurs as highly as men, a lack of role models could perhaps be more to do with women actively avoiding media stereotyping or rejecting engagement with the media. However, in influencing entrepreneurial intent, the existence of positive role models is only one variable in a complex dynamic that includes personal, familial and societal attitudes along with the establishment of social norms that imbue entrepreneurship and business ownership intent.

3.4 SET Entrepreneurship: Technology transfer activities

Transfer of technologies from the research centres and incubators of universities to industry is increasingly regarded as playing a significant role in supporting entrepreneurship and the creation of new business through various programmes (Chell and Allman, 2003; Wright et al., 2004a). The spinning-out of university-based scientific inventions to businesses represents a significant option to create wealth from the commercialisation of research (Wright et al., 2004b). The commercialisation of research has formed a crucial part of the UK Government's industrial and innovation policy over the last decade (Chell and Oakey, 2004). As reported by Chell and Allman (2003: 118) the Government is keen to address a lack of enterprise culture within the education and training system at one level and a lack of technology transfer from universities to industry at another level. To this end, increased funding and investment opportunities are provided for incubators to ensure that support is available for new enterprise formation. There are also improved funding opportunities for the exploitation of technologies (identified by the Foresight exercise) by high technology firms (Chell and Allman, 2003: 118).

One outcome of 1998 Government policy is the establishment of thirteen science enterprise centres within the UK that address the development of scientists and engineers skilled in enterprise and business (Chell and Allman, 2003). The centres are established in cultures of academic excellence in science and engineering and supported by initially by a pump-priming grant from the Office of Science and Technology (OST). Their remit is to work with businesses, foster and promote the

commercialisation of science and technology through enterprise and entrepreneurship, utilising the university research base. These authors note that the programmes offered at some science enterprise centres are fundamentally different than the conventional management courses where the student remains rather distant from the reality of product development. They maintain that the enterprise courses are designed and delivered in accordance with real life patent issues, IP, manufacturing and product evaluation difficulties.

Given this context, it is important to understand the nature of the technology transfer process in relation to the socio- political and economic context. Harmon et al. (1997) outline a number of models describing the process of technology transfer. Some of the existing models (e.g. Goldhor and Lund, 1983, Zhao and Reisman, 1992 and Cole, 1992) characterise this process as a linear progression of steps: from idea generation and technology development at the university, to patenting technology and then establishing a university-private firm link through a formal search process. The process culminates in patents rights transfer. This is criticised for its linearity, which does not reflect the iterative nature of scientific process and discovery. Other models describe technology transfer in terms of networking arrangements and emphasize not so much formal search as the role of a long term relationship between the two parties (Rothwell and Robertson, 1973, McDonald and Geiger, 1987 and Auster, 1990). A third approach is the hybridisation of perspectives, which indicate that it is possible to combine the two approaches - formal search and informal networking arrangements - to ensure successful transfer.

The findings of Harmon et al.'s (1997: 431) study support the second approach i.e. 'relationship' perspective. They argue that the 'formal search and shopping' for a technology model suggests that both business and academic/government laboratories publicise, respectively, their requirements and offerings, and that opportunities for creative brokerage should exist. They found that in the majority of cases that technology was transferred not through formal search, but through

some prior relationships among individuals. This observation highlights the importance of the ability to build extended networks of relationships, not only within the business world but also with the university community, and that it is a crucial skill that owners and managers of technology based businesses need. Their recommendation to nascent entrepreneurs seeking to start businesses based on new technologies is to evaluate how much of their limited time can be allocated to establish and sustain networks and collaborative relationships and how much time to devote to 'shop' for new technologies through formal channels. This suggests that both the public policy makers and university tech transfer offices should shift their emphasis from facilitating 'shopping' by organising and/or paying for 'publicity' to providing assistance in network building and encouraging interpersonal and inter-organisational relationships (Harmon et al., 1997).

In another US study, Neck et al. (2004) provide supporting evidence to this approach and signify the importance of interrelationships in an entrepreneurial context. They explore high-technology venture creation within the context of an entrepreneurial system, the components of which include the incubator-spin off relationship, the need to develop informal and formal networks, aspects of the physical infrastructure, and the prevailing culture. They state that all these components interrelate and interact to form a system conducive to dense- high technology entrepreneurial activity. In a European study, Heirman and Clarysse (2004) develop a resource-based model in examining technology or research based start-ups. The authors place the emphasis on how the initial resources interact with the institutional origin and market characteristics. Their discussion supports the debate pertaining to the interplay of environment and firms resources.

Considering these ideas in a UK context in general, and to the current research in particular, we can argue that it is important to explore the level of interaction between research groups/departments of universities and technology transfer offices. This interaction should be studied by taking a broader view of technology transfer offices in terms of their interface with the outside world. Yet the questions

remain as: What are these formal and informal networks? Do physicists and engineers attract external people to the process of technology transfer? How does the culture of the university and that of their science departments affect these interactions? What are the resource and capability requirements for SET entrepreneurship via technology transfer? And is there a gender dimension to this, such as 'old boys' network? The implications that such an approach may have for women scientists are discussed in section 3.5.

Employing a resource-based framework, Wright et al (2004b) demonstrate that spin-outs typically lack the financial means and managerial expertise to acquire the resources and develop the capabilities they need in order to fully exploit the commercial potential of their technologies. As a means of overcoming some potential problems associated with managing resource weaknesses and insufficient capabilities, Wright et al. (2004b) suggest that creating a spin-out business as a joint venture with an industrial partner may provide a faster, more flexible, less risky and less costly business venturing route to commercialising university intellectual property compared with venture backed university start-ups. Academic entrepreneurs and university technology transfer officers should have sufficient expertise to create viable business propositions because a specific commercial focus and appropriate skills to facilitate the development of an early stage venture are crucial.

Based on a nation-wide survey conducted with 1,000 high technology SMEs in the UK, O'Regan and Ghobadian (2002) report the significance of leadership in high technology firms. Their findings indicate that high technology firms place greater emphasis on leadership than low technology firms do[2]. This argument is supported by Beckinsale and Levy's (2002) paper, which highlights the role of entrepreneurial leader in effective strategy formulation in new technology based

[2] West (2002) makes the distinction between high and low technology firms by using the following measures: growth expectations, capitalisation on a per employee basis, and geographical spread of customer base, sophistication of customer and supply base and emphasis on product development.

businesses. The implication is that training programs for scientists should consider the development of leadership skills as another aspect.

It appears that a multi-level perspective should be taken in investigating the university technology transfer process to fully understand the phenomenon: the firm level, university level, academic entrepreneurs' level coupled with their interaction with the technology transfer officers. Wright et al. (2004a) suggest that how academic entrepreneurs recognise opportunities and shape their ideas to meet the market requirement should be studied in relation to the nature of internal university environments, processes and resources and the nature of scientific discipline as they are likely to have implications for the process of creation and development of spin-out ventures. This echoes Chell and her co-workers, who have argued for research that tracks the development of the academic entrepreneur's learning as they go through different phases of business venturing (Chell and Allman, 2003; Chell and Oakey, 2004).

Analysing a database of Cambridge University spin-outs and providing case study evidence, Druilhe and Garnsey (2004) illustrate how the business models of new ventures are modified as entrepreneurs improve their knowledge of resources and opportunities. Through engagement with others and involvement in entrepreneurial activities, they modify, refine and further develop their business model by shifting –in most cases- through different forms such as from a research contract company to a licensing company or reconsidering starting a product company and develop a technical consultancy instead (Druilhe and Garnsey, 2004: 281). The practical implications –as identified by the authors- include the following points, which support the views presented above. First, the business opportunity of an academic venture can only be realised provided the appropriate partnerships and collaborations can be established. Second, resource requirements for finance and human capital need to be evaluated in relation to actual and potential returns of academic ventures. Third, policy makers should pay greater attention to the diversity of spin-outs, as the potential for creating economic and social value from

these ventures varies greatly, although they all contribute to transferring knowledge from university to industry. Finally, acknowledging the diverse needs of spin-outs and academic entrepreneurs that found them paves the way for providing appropriate support. This has also implications for enterprise educators in terms of engaging in more differentiated support.

3.5 Women and SET Entrepreneurship

Chell (2002) maintains that to achieve the outcome of more female technology entrepreneurs requires a critical examination of prevailing assumptions and questioning of any apparent biased thinking. An entrepreneurial career path may be more attractive to women scientists than is yet apparent. It certainly provides an alternative, potentially more flexible career path. When one compares it to the professional or bureaucratic career paths, it is evident that women, (as indeed would be the case for men), need to be trained more thoroughly in enterprise skills[3].

This review found only one attempt in the UK to quantify and describe women in SET experience of commercialisation in an academic context: Rosa et al, 2004. In examining spin-out companies from 20 universities, the researchers found female-led spin outs at just 12%, representing 21 women. The methodology used to identify such women was, by the authors' admission, not particularly robust, therefore, the 12% figure should not necessarily be considered a reliable guide or even a best estimate. Nevertheless no significant gender differences were found in follow up interviews and questionnaires, though in comparison with male colleagues, women did seem to cite time issues with family responsibilities as a barrier and some women expressed problems with the quality of the support offered by commercialisation offices.

[3] The issues pertaining to the establishment of science enterprise through technology transfer were delineated in section 3.4.

Klofsten and Jones-Evans (1998) examine academic entrepreneurship in Sweden and Ireland, and make the following point that is of relevance to this study: Commercialisation activity by academics appears to be correlated significantly with age and experience of working outside of academia and of previous entrepreneurial experience (either business ownership or family ownership of business). These are two factors that should be explored in future studies.

In sum it would appear that there is not a 'level playing field' for the entry of women into either enterprise or a scientific career; to attempt to enter both may be doubly difficult (Chell, 2002). So, what might be done to understand: (a) the social context of young scientific entrepreneurs, and, (b) the changes that may need to be contemplated to facilitate the entry of women into physics and engineering education and a science enterprise career that are on an equal footing with males?

4. Methodology

The above literature review raises many questions about the extent of women's involvement in science and technology transfer activities. The research studies are not conclusive; indeed there has been a dearth of research that investigates the process of engagement by women in technology transfer. This study takes this gap in our knowledge as the focus of this preliminary investigation. It takes a critical approach, that is, to ensure that we examine whether 'gender' is the issue and to attempt to get a more rounded view of why scientists might engage in tech transfer activities at all. We assume (and test the assumption) that there may well be other issues that apply to both male and female scientists that influence their motivation and intention to engage in technology transfer.

This study seeks to find some quantitative evidence that might differentiate male and female scientists approach to their career, and in particular their possible engagement in technology transfer. For the latter we use as a proxy desire to become involved in founding their own business. Whilst there are subtleties and differences in engagement in technology transfer, the nature of a focused

quantitative survey does not necessarily allow one to explore these subtleties. We have therefore in the second part of our study, carried out a number of qualitative interviews that enable us to delve into underlying motivations so that we have both a detailed understanding and the ability to explain our albeit preliminary findings. The research questions summarised in Table 4.1 that have shaped Part 1 of this study are as follows:

- Is there a difference in attitude and belief about technology transfer activities between male and female physicists?
- Is there any evidence to suggest that women are more reticent in their attitude towards an enterprising career?
- What are the more favoured career choices of male and female physicists and engineers? Are there significant differences in choice by gender and/or differences by subject/discipline?
- Does the selected career choice map on to intention to engage in enterprise activity? (Where 'enterprise activity' includes technology transfer and/or business founding).
- Are there any measurable cultural factors that might influence physicists' orientation towards technology transfer activity and an enterprising career?
- Are there any person-specific factors such as age that might influence physicists' orientation towards technology transfer activity and an enterprising career?
- What kind, if any, pressure from significant others do physicists/engineers experience in making career choices, including that of engaging in enterprise activity.

The study is furthered in Part 2 where we attempt to address the following questions (see Table 4.1):

- What is the nature of the process of technology transfer as experienced by female and male physicists and engineers (i.e. how an idea with potential

for technology transfer is identified, developed and moved into incubation)?

- Are there any gender differences in the process?

Part 1 – the quantitative survey – is based on an established theoretical framework entitled the 'theory of planned behaviour' (Ajzen, 1991, 2002). Part 2 – the qualitative survey – comprises focus group and a semi-structured interview schedule that follows closely the issues raised in the quantitative survey that probes for deeper understanding. The next section outlines these two parts to the research design in more detail.

Table 4.1 Research questions and methods

	Research questions	Secondary research methods	Primary research methods	Sample drawn from
Part 1 **Quantitative Survey**	• Is there a difference in attitude and belief about technology transfer activities between male and female physicists? • Is there any evidence to suggest that women are more reticent in their attitude towards an enterprising career? • What are the more favoured career choices of male and female physicists and engineers? Are there significant differences in choice by gender and/or differences by subject/discipline? • Does the selected career choice map on to intention to engage in enterprise activity? (Where 'enterprise activity' includes technology transfer and/or business founding). • Are there any measurable cultural factors that might influence physicists' orientation towards technology transfer activity and an enterprising career? • Are there any person-specific factors such as age that might influence physicists' orientation towards technology transfer activity and an enterprising career?	Literature review	Quantitative survey based on a TBP questionnaire	Postgraduate students, post-doctoral researchers and staff from Physics and Engineering departments of the following universities: University of Southampton University of Cambridge University of Bath
Part 2 **Qualitative Survey**	▪ What is the nature of the process of technology transfer as experienced by female and male physicists and engineers (i.e. how an idea with potential for technology transfer is identified, developed and moved into incubation)? ▪ Are there any gender differences in the process?	Literature review	Focus group 1 Focus group 2 Semi-structured interviews	Postgraduate students and post-doctoral researchers from Physics and Engineering departments of the University of Southampton Female and male academics from Physics and Engineering departments of the University of Southampton Female and male scientists who engaged in technology transfer activities (from three institutions) Technology transfer officers (from three institutions)

4. 1 Research design and associated methods

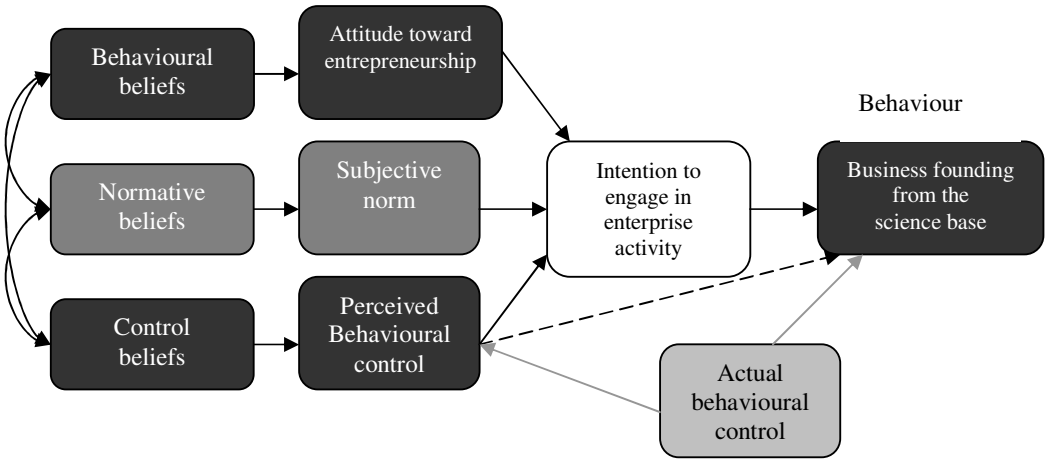
The complexity of the research is addressed in this study by using Ajzen's (1991) theory of planned behaviour (TPB) as the overarching theoretical framework, which integrates three factors determining intentions: (a) attitude toward the behaviour in question, (b) subjective norm and c) the degree of perceived behavioural control.

4.2 Design of the questionnaire: Measurement of entrepreneurial intent

The questionnaire as the main research instrument was constructed by utilising the theory of planned behaviour (TPB) (Ajzen, 1991 and 2002) as the underlying framework[4]. According to the TPB, there are three antecedents of intention: behavioural beliefs, normative beliefs and control beliefs. The *behavioural beliefs* refer to beliefs about the likely outcomes of the behaviour in question and the appraisals of these outcomes. They generate a favourable or unfavourable *attitude toward the behaviour*. The *normative beliefs* refer to beliefs about the normative expectations of others and motivation to comply with these expectations (Ajzen, 2002). The normative beliefs result in *subjective norm* which refers to the perceived social pressure to perform or not perform the behaviour. The *control beliefs* denote beliefs about the presence of factors that may facilitate or impede performance of the behaviour and the perceived power of these factors. They lead to *perceived behavioural control*, which refers to the perceived ease of performing the behaviour and to the perceived control over the outcome of it. The more favourable the attitude and subjective norm with respect to the behaviour, and the greater the perceived behavioural control, the stronger should be an individual's intention to perform the behaviour (Autio et al., 2001). A schematic representation of the theory is shown in Figure 4.1 below.

Figure 4.1 Illustration of Ajzen's theory of planned behaviour

[4] This is a generic theory of planned behaviour. Thus, when applied to this research, the "behaviour" is construed to mean 'enterprise activity, specifically technology transfer and business spinout from the science base'.



The theory of planned behaviour has been increasingly applied in the field of entrepreneurship since 1990s (Krueger, 1993; Krueger and Carsrud, 1993; Krueger and Brazeal, 1994; Davidsson, 1995; Kolvereid, 1997; Krueger et al., 2000; Autio et al., 2001, Luthje, C. and Franke, N., 2003; Peterman and Kennedy, 2003). The theory of planned behaviour has been used together with expectancy-driven theories (Shapero, 1975, 1982; Bird, 1988). As stated by Autio et al. (2001), the main difference between the two theoretical frameworks is that subjective norm is replaced by propensity to act in Shapero's expectancy model. Ajzen's theory of planned behaviour places more emphasis on social norms, whereas Shapero's expectancy theory stresses the characteristics and previous entrepreneurial experience of the individual. However, in this study we have chosen to apply Azjen's model, though we acknowledge that a wider study that included in the sample in-company sources of technology transfer activity, prior entrepreneurial experience would be a factor that we would want to take into account.

The research instrument we devised for this study consists of eleven sections and fifty two questions in total (see Appendix 4a). The sections include 1) entrepreneurial intent, 2) attitude, 3) subjective norms, 4) perceived behavioural controls, 5) outcome evaluation, 6) belief strength, 7) normative beliefs, 8) motivation to comply, 9) strength of control beliefs, 10) observed behaviour and 11) demographic data. The Table in Appendix 4a illustrates items in each section.

The items, excluding the two open-ended questions, two observed behaviour questions and demographic data questions, are based on a 7 point Likert scale.

4.3 Sampling

The empirical study upon which the authors draw in this report investigated the women physicists and engineers' choices and involvement in science enterprise formation in three institutions: University of Southampton, University of Cambridge and University of Bath. It will be widened to include other universities in the follow-up study. Drawing on our discussions with the IoP, we employed a convenience sampling method and framed our sample for the pilot study with three Russell Group universities, University of Southampton and University of Cambridge, both of which have 5* rated Physics and Engineering departments according to the 2001 RAE, and University of Bath, which has a 4 rated Physics department.

Part 1 consisted of a web based questionnaire undertaken with the sample drawn from all three institutions and a focus group research with the postgraduate students and staff drawn from Physics and Engineering departments of the University of Southampton. The questionnaire was designed as a web-based survey and the respondents were sent an e-mail, which explained the research project and invited them to complete the questionnaire by simply clicking the web link provided. It was distributed to 1,236 academics[5] and 215 responses were received, which generated a response rate of 17 %.

Part 2 comprises a qualitative survey achieved through a focus group study and semi-structured interviews. The focus group method was used to test for explanations that emanate from our findings from the questionnaire. It is noted by Hindle (2004) that focus groups are under-utilised in entrepreneurship research. The author attributes the importance of focus groups as a data collection method to its characteristics such as organized discussion, collective activity and interaction

[5] Post-graduate students (including PhD students), lecturing and research staff were included.

among the respondents. Focus groups rely on the interaction within the group based on topics that are supplied by the researcher (Morgan, 1997). The topic guide in this research was constructed by using the TPB and therefore it had three sections: attitudes towards 'enterprise activity', social norms i.e. social/peer pressure in respect of the participant's involvement or otherwise in 'enterprise activity', and behavioural control, that is, the extent to which they believed that if they engaged in 'enterprise activity' they would feel in control of the process and outcome(s). This topic guide was communicated to the participants at the outset of the focus group activity.

The interviews were conducted by mainly two groups of participants: a) female and male academics that have been involved in enterprise activity and b) technology transfer officers in all three Universities. The interviews with the scientists were structured by using the TPB again whereas technology transfer officers were interviewed by taking a multi-dimensional approach which has three interrelated components: process, context and gender.

5. Research findings

5.1 Part One: Quantitative Survey

The overall objective of this research is to "identify what reasons lay behind women physicists and engineers' choices for not exploiting scientific knowledge either in the form of professional employment or setting up an enterprise". We chose to interpret this question in the following way. Fundamentally, we wished to know whether there are gender differences in women's intention to engage in the exploitation of their IP and to do this by setting up their own business. The findings, which we present below, are exploratory and encouraging.

5.11 Intention to engage in enterprise activity

The internal consistency for this measure was satisfactory, yielding a Cronbach's alpha measure of .963 and inter-item correlations from .838 to .901. The measure was recoded to show that the higher the score the stronger the intention. The mean score was 4.08, s.d. = 2.01, n = 205 (of which there were 36 female respondents). The median was found to be 4, the interquartile (IR) range = 4 and the responses were not normally distributed.

5.111 Intention by gender

Table 5.211 Intention by Gender

	Male	Female
Mean	4.19	3.42
SD	2.02	1.93
Median	4.25	2.88
IR	3.75	3

Non-parametric test: Mann-Whitney's U = 2431, *p = .058*
Not significant at 5% level.

Whilst these results were only marginally significant, they are in the expected direction, that is, women's intention was weaker than that of the male sample. It is also likely that a larger sample would have yielded a significant result.

5.112 Intention by subject area

Table 5.212 Intention by subject area

	Physics	Engineering
Mean	3.68	4.45
SD	2.02	1.95
Median	3.5	4.75
IR	3.75	3.75

Non-parametric test: Mann-Whitney's U = 3607, **p = .005**
This result is significant at 1% level.

These results clearly demonstrate a much stronger intention on the part of engineering students towards business start up.

5.113 Intention by Age Group

Table 5.213 Intention by age group

	Up to 25	26-30	31-40	41-50	51+
Mean	4.27	4.13	4.3	3.8	2.61
SD	1.89	1.96	2.11	2.32	1.95
Median	4.5	4.25	4.25	3.25	2.0
IR	3.56	3.44	4.25	4.88	2.56

Non-parametric test: Kruskal-Wallis chi square = 11.438, **p =.022**
This result is significant at 5% level.

The younger age group (up to 25) showed the strongest intention to start a business.

5.114 Intention by Business Experience

Table 5.1141 Intention by previous business activity

	Yes	No
Mean	5.18	3.67
SD	2.01	1.89
Median	6.0	3.75
IR	3.5	3.25

Non-parametric test: Mann-Whitney's U = 1965**, p < .001**
This is significant at 1% level.

Table 5.1142 Intention by current business activity

	Yes	No
Mean	6.03	3.84
SD	1.62	1.96
Median	7.0	4.0
IR	2.0	3.5

Non-parametric test: Mann-Whitney's U = 604.5, **p < .001**

This is significant at 1% level.

The above Tables demonstrate clearly that intention was stronger where there had been prior business activity and even stronger where there was current business activity.

5.12 Attitude towards Starting a Business (direct measure)

There are six items in this scale; however, item 2 showed low correlations with the other items, it was therefore omitted. Omitting item 2, inter-item correlations ranged from .722 to .834 and Cronbach's alpha = .943. The mean = 4.82, s.d. = 1.54 (revealed a skewed distribution, but with no outliers). The median = 4.8, interquartile range = 2.

Table 5.121Attitude by gender

	Male	Female
Mean	4.81	4.63
SD	1.55	1.5
Median	4.9	4.6
	2.2	1.6

Non-parametric test: Mann-Whitney's U = 2728, *p = .517ns*
Not significant at 5% level.

Table 5.122 Attitude by subject area

	Physics	Engineering
Mean	4.61	4.96
SD	1.58	1.48
Median	4.6	5.2
	2.05	2.2

Non-parametric test: Mann-Whitney's U = 3967*, p = .151ns*
Not *significant at 5% level.*

Table 5.123 Attitude by age group

	Up to 25	26-30	31-40	41-50	51+
Mean	4.93	4.89	4.82	4.73	3.63
SD	1.42	1.42	1.63	1.57	1.93
Median	5.2	5	4.7	4.6	3.8
IR	1.8	2.3	2.25	2	3.4

Non-parametric test: Kruskal-Wallis chi square = 5.79*, p =.215ns*
Not significant at 5% level.

Correlation of attitude with intention was high:
Spearman's rho = .840

The results revealed very positive attitudes towards business start up and there were no significant differences by gender, subject area or by age. The correlation with intention was high (Spearman's rho = .840). This is supported by the findings of the qualitative study as will be discussed in section 5.3.

5.13 Subjective Norm

Subjective norms are a person's socially received, implicit 'rules' or 'expectations that help shape attitudes. By their very nature they are difficult to measure and require very careful qualitative design work, if they are to be correctly identified and measured. In this pilot survey, this measure of four items proved to be problematic and in a main survey we would elect to do further work on the measure itself. As it was, the inter-correlations were low and it was decided to use each norm as a separate measure:

Cronbach's alpha = .719
Inter-item correlations .223 to .519, item-total correlations .402 to .685.
There was poor internal consistency but Cronbach's alpha reduces if any items are omitted.

Table 5.131 Results for Each Norm

	Mean	SD
Norm 1	5.52	1.52
Norm 2	4.84	1.69
Norm 3	3.90	1.91
Norm 4	4.62	1.60

The only norm from the above that yield significant results was Norm 3, which is 'at some point in my career, I will be expected to start a business' (1=extremely likely, 7=extremely unlikely). The following statistically significant results were generated:

Table 5.131 Subjective Norms By gender (Mann-Whitney U Test)

	Male		Female		
	Mean	SD	Mean	SD	p value
Norm 1	5.44	1.49	5.83	1.44	.166
Norm 2	4.80	1.75	4.67	1.47	.433
Norm 3	4.00	1.90	3.14	1.64	**.017**
Norm 4	4.62	1.60	4.61	1.83	.659

The female sample thought it **less likely** than the male sample that they would be expected to start a business, at some point in their career. There was no difference by age.

Table 5.132 Subjective Norms By subject area: Mann-Whitney U Tests

	Physics		Engineering		
	Mean	SD	Mean	SD	p value
Norm 1	5.52	1.59	5.52	1.39	.900
Norm 2	4.66	1.73	4.90	1.66	.136
Norm 3	3.54	1.87	4.16	1.85	**.007**
Norm 4	4.60	1.68	4.65	1.61	.856

The engineers in the sample thought it **more likely** than the physicists that they would be expected to start a business at some point in their career. There was no difference by age.

5.133 Subjective Norms by Age

Table 5.133 Subjective Norms by Age: Kruskal-Wallis Test

Age group	Norm1		Norm2		Norm3		Norm4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Up to 25	5.69	1.39	5.08	1.53	4.03	1.86	4.74	2.36
26-30	5.92	1.35	4.80	1.71	3.89	1.76	4.67	1.76
31-40	5.14	1.38	4.75	1.57	3.81	1.93	4.50	1.48
41-50	5.00	1.58	4.78	2.22	3.78	2.33	4.22	2.44
51+	4.44	1.82	3.67	1.85	3.06	2.07	4.50	1.51
p value	**<.001**		.09		.604		.866	

Norm 1: My family would be supportive or unsupportive of me in setting up a business

This showed that up to the age of 30, the respondent expected the family would be supportive, but beyond that, **with increasing age**, it was believed that **the family would be increasingly less supportive**. This finding was **statistically significant**.

Norm 2: People whose opinions I value would think that I should/should not start a business

This showed that as the person aged the less people would think they should start a business. Whilst this finding is suggestive it did not reach statistical significance at 5% level.

The correlation with intention was low for norm 1, Spearman's rho = .373, for norm 2, Spearman's rho = .677, for norm 3, Spearman's rho = .690 and for norm 4, Spearman's rho = .537.

5.14 Perceived Behavioural Control

This measure showed poor internal consistency and so we again decided to treat each item as an independent measure:

Cronbach's alpha = .735

Inter-item correlation low, except 3 and 4 = .666 (reasonable).

Item total correlations ranged from.422 to .586. Cronbach's Alpha was found to increase if item 1 is deleted, reduces for others. Thus, there was found to be poor inter-item consistency. The measures are reproduced below for convenience.

Control 1: 'For me to set up in business within ten years is 1=impossible – 7 = possible'

Control 2: 'If I wanted to I could set up my own business in the next ten years' 1= definitely false, 7= definitely true

Control 3: 'How much control do you feel you have over whether you would set up your own business?' 1=no control, 7=complete control

Control 4: It is mostly up to me whether I set up my own business' 1= strongly disagree, 7 = strongly agree

NB: For purposes of the analysis, the questions were recoded so that '7' was the positive response.

5.141 Perceived Behavioural Control by Gender

Table 5.141 Perceived behavioural control by gender: Mann-Whitney tests

	Male (mean)	Female (mean)	p value
Control 1	5.19	4.92	.274
Control 2	5.30	5.25	.934
Control 3	5.37	5.47	.366
Control 4	5.50	5.72	.181

We found no meaningful differences between genders on any of the four items. Overall the perceived behavioural control scale by gender showed identical means:

Mann-Whitney tests

Male (mean)	Female (mean)	p value
5.34	5.34	*.835 n.s.*

5.142 Perceived Behavioural Control by Subject Area

As regards subject area, the engineers showed stronger perceived behavioural control in respect of items 1,2 and 4 (see Table 5.142) below.

Table 5.142 Perceived behavioural control by subject area: Mann-Whitney tests

	Physics (mean)	Engineering (mean)	p value
Control 1	4.86	5.43	**.019***
Control 2	5.02	5.58	**.030***
Control 3	5.34	5.44	.792
Control 4	5.31	5.78	**.028***

The overall analysis for perceived behavioural control by subject area was **statistically significant at p= 0.031*** (Mann-Whitney U Test), as shown below:

Physics (mean)	Engineering (mean)	p value
5.13	5.56	**.031***

5.143 Perceived Behavioural Control by Age

Table 5.143 Perceived behavioural control by age group: Kruskal-Wallis

	Up to 25 (mean)	26-30 (mean)	31-40 (mean)	41-50 (mean)	51+ (mean)	p value
Control 1	5.19	5.42	4.70	5.33	4.67	.431
Control 2	5.11	5.56	5.51	5.00	4.61	.418
Control 3	5.16	5.44	5.41	5.11	6.11	**.027***
Control 4	5.48	5.42	5.54	5.11	6.39	.305

The independent measure (Control 3) – showed that the older age group (51+) felt that they had almost complete control over whether they would set up in business; this was not true for the respondents aged 50 and younger.

Overall there was no statistically significant difference between respondents' perception of behavioural control and age:

Kruskal-Wallis test

Up to 25 (mean)	26-30 (mean)	31-40 (mean)	41-50 (mean)	51+ (mean)	p value
5.24	5.46	5.29	5.14	5.63	*.888 n.s.*

The correlation of Perceived behavioural control scale with intention was very low, Spearman's rho = .372.

5.15 Behavioural Belief (indirect measure)

The uni-polar measure of behavioural belief was derived by pairing 'outcome evaluation' with the 'belief strength' scale and multiplying each paired result. Each scale ranged from 1 to 7 and so each score could range from 2 to 49. The mean score = 41.39, s.d. = 22.97. There was a slight skew, but the central limit theorem applied and so it was possible to use parametric statistics. The correlation with the direct measure of attitude was: Pearson's r = .631.

5.151 Behavioural belief by gender

No significant difference in gender was found. However, both male and female respondents had a relatively strong belief in their ability to set up in business and both become wealthy and produce social benefits as a consequence.

Table 5.151 Uni-polar t test of behavioural belief by gender

Male (mean)	SD	Female (mean)	SD	t	p value
40.82	23.16	38.33	18.12	.293	*.770 n.s.*

5.152 Behavioural belief by subject area

Both the Engineering and Physics respondents placed a relatively positive value on becoming wealthy and creating social benefits through setting up their own business. They also believed that on balance it was likely that within the space of 10 years that this would result in them becoming wealthy and creating social

benefits. **The Engineering respondents, however, had a much stronger belief, which was statistically significant at p=0.01**.

Table 5.152 Uni-polar scale t-test of Behavioural belief by subject area

Physics (mean)	SD	Engineering (mean)	SD	t	p value
36.87	19.67	43.95	24.26	-2.584	**.010***

5.153 Behavioural Belief by Age

A one way ANOVA test was conducted to test for differences in belief strength by age of respondent. This revealed that the younger the respondents the more positive their belief strength. There was a big drop in belief strength at the age 40. **The results are statistically significant at p= 0.01**.

Table 5.153 One Way ANOVA Behavioural Belief by Age

	Up to 25	26-30	31-40	41-50	51+	p value
Mean	45.92	40.07	43.18	25.56	23.29	**.010***
SD	20.79	20.89	23.80	16.82	21.84	

5.154 Correlation with Intention

There was found to be a modest correlation between the indirect measure of behavioural belief and intention. Pearson's rho = .598.

5.155 Further descriptive statistics and analyses: behavioural belief by outcome evaluation

Appendix 5a contains the descriptive statistics for outcome evaluation and belief strength. These measures seek to distinguish between the fact that someone might have a positive attitude towards a particular outcome (say, wealth creation) whilst believing that it is unlikely that they would pursue/achieve such an outcome.

In summary, Appendix 5a shows:

- The frequencies and distribution of each of the four original variables. The distributions are not normal. We have therefore used non-parametric statistical analyses.
- The behavioural belief score for wealth (q14*q17) and for social benefits (q15*q18), and the descriptive statistics and plots for each separately
- All analyses are shown by sex, subject area and age group

The findings shown in detail in Appendix 5a are also presented in summary:

- Tests for difference between groups by sex show no statistically significant difference. It is worth noting, however, that there was a more positive attitude towards belief in the ability to create wealth by the male sample. The lack of statistical significance could be a consequence of the relatively small sample of female respondents (n=36) and so should be tested further on a larger sample.
- Engineers rate wealth significantly higher than do Physicists, but there was no difference on social benefits (Kruskal Wallis Test; Z= -2.441; **p= .015*).**
- Age group is significant on both variables, the results demonstrate a step change in attitude and belief strength by the two older age groups (over 40 years); Chi square test for wealth, p=.004; for social benefits**, p=.009****)
- When we compared wealth versus social benefits, social benefits were rated significantly more than wealth (Wilcoxon signed ranks test, Z= -3.944**, p=.000*****)
- The latter result holds for males and females separately; (Wilcoxon signed ranks test, male sample, Z= -2.603, p=.009; female sample, Z= -3.272, p**=.001****)
- Physicists rate social benefits more highly than wealth, but Engineers rated them both equally. Wilcoxon signed ranks test (Physicists) Z=-3.658, p=.000; (Engineers) Z= -1.784, *p=.074ns*

- When we created two age groups – under 40 and 40+, social benefits are rated more highly than wealth by both groups. Wilcoxon signed ranks test for Under 40, Z= -3.006, p= .003; Group 40 +, = -2.854, **p= .004****

5.16 Evaluation of own Intellectual Property (IP)

Question 16 asked the respondents to evaluate whether the commercial exploitation of IP is of high or low value to them. The results showed a highly statistically significant difference between genders, with male respondents indicating the higher value (**p=0.005****).

Table 5.161 Evaluation of the Commercial Exploitation of Own IP by Gender

Male (mean)	Female (mean)	p value
4.74	3.97	**.005****

There was no difference between physicists and engineers on this question, and there was a marginal statistically significant difference arising with age (**p=0.066**).

Table 5.162 Evaluation of the Commercial Exploitation of Own IP by Subject

Physics (mean)	Engineering (mean)	p value
4.54	4.66	*.764 n.s.*

Table 5.163 Evaluation of the Commercial Exploitation of Own IP by Age (Kruskal-Wallis Test)

Up to 25 (mean)	26-30 (mean)	31-40 (mean)	41-50 (mean)	51+ (mean)	p value
4.81	4.57	4.86	4.56	3.41	**.066**

There was a good correlation between commercial exploitation and intention to start a business (Spearman's rho = .623).

5.17 Normative Beliefs (indirect measure)

There were four indirect measures of normative beliefs:

Q 25 'My supervisor thinks that my starting a business is a good thing' (1= definitely false; 7= definitely true)

Q 27 'My family thinks that my starting a business is a good thing' (1= definitely false; 7= definitely true)

Q 28 'My peers think that my starting a business is a good thing' (1= definitely false; 7= definitely true)

Q 29 'Other people who are important in my life think that my starting a business is a good thing' (1= definitely false; 7= definitely true)

This measure did not reveal internally consistent results. The questions were numbers 25, 27 to 29 inclusive. Further work on this scale is needed. The uni-polar results revealed a mean = 73.30, s.d. = 30.39. Correlations were made with the direct measure of subjective norms (questions 6-9), Spearman's rho = .472. Correlations with each subjective norm (1-4) were carried out, with results ranging from .226 to .406. Clearly these are very low.

As the following tables reveal there was no significant difference between gender and subject area, and only marginal significance as a result of age.

Table 5.171 Uni-polar Scale: t test of normative belief by gender

Male (mean)	SD	Female (mean)	SD	t	p value
73.98	30.08	69.19	32.62	.841	*.402 n.s.*

Table 5.172 Uni-polar scale: t test of normative belief by subject

Physics (mean)	SD	Engineering (mean)	SD	t	p value
70.92	29.99	76.19	30.85	-1.173	*.242 n.s.*

Table 5.173 ANOVA of normative belief by age

	Up to 25	26-30	31-40	41-50	51+	p value
Mean	83.17	70.41	69.53	70.89	62.63	**.052***
SD	31.98	27.53	30.73	38.99	24.34	

Whilst normative beliefs were most strongly held amongst the youngest group (<25years), post hoc comparisons showed that no two particular groups were statistically significantly different.

Correlation with intention showed Spearman's rho = .379.

We firmly believe that this measure would need to be readdressed.

5.18 Strength of Control Beliefs (indirect measure)

There were 4 measures:

Q34: 'How hard do you think it would be to raise finance to start a business in ten years?' 1= very hard to 7 = very easy
Q35: 'How certain are you that you could start a successful business in ten years?'1= very uncertain, 7= very certain
Q36: 'How overworked would you be in trying to start a business within ten years?' 1= very overworked, 7 = not very overworked
Q37: 'How stressed would you be in trying to start a business within ten years?' 1= very stressed, 7= not very stressed

This measure revealed a mean score of 2.65, s.d. = 1.01, median = 2.75, IR = .5. Correlations were carried out with Perceived Behavioural control using Spearman's rho. Overall rho= .389

Control 1	rho = .394
Control 2	rho = .362
Control 3	rho = .166
Control 4	rho = .165

5.181 Gender differences in control beliefs

In general the respondents thought that it would be difficult (hard or whatever) to start a business in the next ten years. Male subjects indicated that it would be slightly easier than did females.

Table 5.181 Results from a T-test by Gender and Control Beliefs

Male (mean)	SD	Female (mean)	SD	t	p value
2.74	1.03	2.29	0.87	2.496	**.013***

Table 5.182 Results from a T-test by Subject and Control Beliefs

Physics (mean)	SD	Engineering (mean)	SD	t	p value
2.50	0.98	2.85	1.01	-2.443	**.015***

Table 5.183 Results from One-way ANOVA by Age and Control Beliefs

	Up to 25	26-30	31-40	41-50	51+	p value
Mean	2.68	2.75	2.53	2.39	2.85	*.657 n.s.*
SD	1.06	0.85	1.00	0.76	1.43	

Control beliefs were modestly correlated with Intention, Spearman's rho= .543.

5.19 Career Choices

As discussed in section 3, career choice for physics and engineering students is likely to be shaped by university-departmental culture (for example, a strong research-academic ethos), industry influences, the individuals orientation to the subject and to work, peer and family pressures. Whilst we have been unable to demonstrate these influences to our satisfaction using the TPB questionnaire constructed and piloted for the purpose, our separate measure of career choices was indicative.

Table 5.191 Differences in Career Choice

	Academic	Entrepreneurial	Corporate	Civil Service
Mean	5.38	4.55	4.30	3.63
SD	1.72	1.77	1.85	1.76

Freidman test: chi square = 95.11, **p < .001****

Table 5.191 shows the results of analysis of choice between academic, entrepreneurial, corporate or civil services careers. The academic career was selected as the most desirable, with the entrepreneurial career as the next most desirable. The results are statistically significant at **p<.001**. A Wilcoxon pairs test was carried out and showed significant differences at the 5% level, except for the pair entrepreneurial/corporate. Clearly some further work, probably using a larger sample, and also qualitative work to be able to explain such findings is needed. Career choices by gender were not significantly different, suggesting that cultural differences and factors that shaped the individual's orientation to the subject were stronger.

Table 5.192 Career Choices by Subject Area

	Physics (mean)	SD	Engineering (mean)	SD
Academic	5.65	1.54.	5.14	1.85
Entrepreneurial	4.30	1.85	4.79	1.64
Corporate	4.18	1.86	4.41	1.83
Civil Service	3.83	1.81	3.41	1.67
pvalue	**< .001***		**< .001***	

Table 5.192 shows career choices by subject area. Ideally a larger sample would be needed to demonstrate whether there is a significant difference between Physics and Engineering along the rows. However, within each subject domain there was an overall statistically significant difference between career choice at p<.001. Further analysis using Wilcoxon tests of pairs showed that within the Physics sample choice of an academic career was significantly greater than all the others and that there were no other significant differences. For Engineering, choice of a career in the civil service was significantly lower than all others; there were no other significant differences.

The only career choice that correlated with 'intention' was choice of an entrepreneurial career. This aspect of internal consistency is of course what one would have hoped for! The results of Spearman's rho are presented below (see Table 5.193).

Table 5.193 Correlation of Career Choice with Intention to start a business

	rho
Academic	-.197
Entrepreneurial	**.788***
Corporate	.204
Civil Service	-.134

Table 5.194 Summary of Key Findings

1. Intention to engage in enterprise activity		
By gender:	Mann-Whitney's U = 2431	*p = .058n.s*
By subject:	Mann-Whitney's U = 3607	**p = .005****
By Age:	Kruskal-Wallis chi square = 11.438	**p =.022***
By business experience:	Mann-Whitney's U = 1965	**p < .001****
By current business activity:	Mann-Whitney's U = 604.5	**p < .001**
2. Attitude toward starting a business		
By gender:	Mann-Whitney's U = 2728	*p = .517ns*
By subject:	Mann-Whitney's U = 3967	*p = .151ns*
By age:	Kruskal-Wallis chi square = 5.79	*p =.215ns*
	---------- Correlation between attitude and intention: **Spearman's rho**	r =.840
3. Subjective Norms		
By gender:	Women thought it less likely that they would be expected to start a business at some point in their career M-W U =	**p= .017***
By subject area:	Engineers thought it more likely that they would be expected to start a business than physicists at some point in their career; M-W U =	**p = .007****

By age:	< 30 years, respondent expected family to be supportive; with increasing age beyond 30 years, family believed to be increasingly less supportive, Kruskal-Wallis	**p = .001****
4. Perceived Behavioural Control		
By gender:	No significantly different results M-W U	*p =.835ns*
By subject:	Engineers had a stronger perception of control than Physicists, M-W U	**p = .031***
By age:	age 51+ felt they had almost complete control over whether or not they would start a business in contrast to younger respondents, Kruskal-Wallis	**p = .027***
5. Behavioural Beliefs	Correlation with attitude: Pearson's rho	r = .631
By gender:	---------- Both a relatively strong belief in ability to set up and business & produce econ & social benefits, t = .293	*p = .770n.s.*
By subject:	Engineers a stronger belief in ability to set up and business & produce econ & social benefits, t = -2.584	**p = .01****
By age:	<40 stronger belief strength, ANOVA ---------- Correlation with intention, Pearson's rho	**p = .01**** r = .598
6. Evaluation of Own IP		
By gender:	Males rated their IP higher	**p = .005****
By subject:		*p = .764 n.s.*
By age:	lower value > 51	**p = .066**
7. Normative Beliefs		
By gender:	Generally positive, t test .841	*p = 402 n.s.*
By subject:	Generally positive, t test -1.173	*p = .242n.s*
By age:	The younger the more positive, ANOVA	**p = .052***
8. Strength of Control Beliefs		
By gender:	difficult to start a business, but males thought it would be slightly easier than did females, t = 2.496	**p = .013****
By subject:	Difficult to start a business, but Engineers	

By age:	thought it would be slightly easier than did physicists, t = -2.443 ANOVA of 5 age groups,	**p = .015**** *p = .657 n.s.*
9. Career Choices All respondents: By subject: By subject:	Career preference, was rated academic, entrepreneurial, corporate and civil service Chi sq = 95.11 Within Physics, preferences were for academic, entrepreneurial, corporate and last civil service career Within Engineering, preferences were for academic, entrepreneurial, corporate and last civil service career --- Career preference for civil service was sig. lower than for all others for engineers	**p = .001***** **p = .001***** **p = .001*****
10 Correlations of Career Choice and Intention Academic Entrepreneurial Corporate Civil service	 Spearman's rho Spearman's rho Spearman's rho Spearman's rho	 r = -.197 r = **.788** r = .204 r = -.134

5.20 Perceived Advantages of Setting up a Business

Question 19 asked the respondents to state three advantages that they might perceive in setting up a business. The answers to this open-ended question were examined by using Miles and Huberman's (1994) data coding technique[6] and the following categories were created:

[6] Miles and Huberman (1994) put forward a number of coding techniques in their useful book entitled 'An Expanded Sourcebook: Qualitative Data Analysis'. The one that we employed in this research is an inductive coding technique, which originally derives from the 'grounded approach' (Glaser and Strauss, 1967, Strauss, 1987 and Strauss and Corbin, 1990). It is best described in Strauss and Corbin (1998): Initial data are collected, written-up and reviewed line by line. For each response section (it would be paragraphs in an interview transcript) categories and subcategories are generated and a list of them grows. The categories are reviewed at the end and reprocessed by condensing or extending the subcategories. Then they are put onto a qualitative data category table (5.201 and 5.211 in this research).

Table 5.201 Perceived Advantages of Setting up a Business by Category

Category	Code
Wealth creation	WeC
Income generation	WeC-IG
Profit generation	WeC-PG
Capital accumulation	WeC-CA
Employment creation	EmC
Ownership and locus of control	OLC
Autonomy and leadership	OLC-AL
Control of own destiny/future	OLC-CoD
Control over business	OLC-CoB
Ethical control over operations	OLC-ECO
Financial flexibility	OLC-FF
Commercial use of research	CUR
New product development	CUR- NPD
Innovation	CUR-I
Research methods	CUR- RM
Knowledge (or Technology) transfer	CUR-KTT
Social value creation	SVC
Social contribution	SVC-SC
Making social use of research	SVC-MUR
Acquisition of enterprising competency	AEC
Business knowledge	AEC-BK
Experience	AEC-E
Skills development	AEC-SD
Learning by doing	AEC-LD
Attainment of personal goals	APG
Motivation for personal achievement	APG-MPA
Self-esteem	APG-SE
Reward	APG-R
Self-realisation	APG-SR
Enjoyment	APG-E
Challenge	APG-C
Success	APG-S
Tax advantages	TA
More desirable career option	CO
Enabling to overcome difficulties/ Problems associated with academic work	CO-AW
Lifestyle changes	CO-LC
Providing for family	CO-PF
Career development	CO-CD
Better social relationships	CO-BSR

The frequencies for each category by gender were observed as follows:

Table 5.202 Perceived Advantages of setting up a Business by Sex of Respondent

Category	*Male*			*Female*		
	1st response	2nd response	3rd response	1st response	2nd response	3rd response
WeC	23	21	16	5	6	3
%	**20.5**	16.8	13.6	14.3	17.6	9.4
EC	2	5	5	---	---	1
%	1.8	4.0	4.2	---	---	3.1
OLC	53	35	20	17	11	10
%	**47.3**	28.0	17.0	**48.6**	32.3	31.2
CUR	4	9	1	---	1	1
%	3.6	7.2	0.8	---	3.0	3.1
SVC	6	6	13	2	1	3
%	5.3	4.8	11.0	5.7	3.0	9.4
AEC	4	7	9	---	1	1
%	3.6	5.6	7.6	---	3.0	3.1
APG	14	32	29	8	8	7
%	**12.5**	25.6	24.6	**22.9**	23.5	21.9
TA	2	---	1	---	---	---
%	1.8	---	0.8	---	---	---
CO	4	10	24	3	6	6
%	3.6	8.0	20.4	8.5	17.6	18.8
Total number of valid entries	112	125	118	35	34	32
Total (%)	100	100	100	100	100	100

'Ownership and locus of control' appears to be the most important perceived advantage for both female (48.6 %) and male (47.3 %) respondents. For the male respondents this is followed by 'wealth creation' (20.5 %) whereas it is 'attainment of personal goals' for the female respondents (22.9 %). 'Attainment of personal goals' becomes important for male respondents particularly in their second (25.6 %) and third (24.6 %) answers to the question. Setting up a business is associated with an 'entrepreneurial career' by some respondents. It is perceived to be a more desirable career option in the third answer given to the question by both male (20.4 %) and female (18.8 %) respondents. We suggest that in the subsequent main

study subjects are asked to rank their choices of advantages; this will facilitate a more sensitive analysis.

The frequencies for each category by subject area were observed as follows:

Table 5.203 Perceived Advantages of Setting up a Business by Subject

Category	**Physics**			**Engineering**		
	1st response	2nd response	3rd response	1st response	2nd response	3rd response
WeC	17	15	10	13	9	10
%	**22.4**	18.5	13.4	**17.3**	12.0	13.9
EC	1	2	5	1	2	2
%	1.3	2.5	6.7	1.3	2.7	2.8
OLC	37	22	18	35	27	9
%	**48.7**	**27.2**	**24.0**	**46.7**	**36.0**	12.5
CUR	4	5	1	---	4	1
%	5.3	6.2	1.3	---	5.3	1.4
SVC	2	4	8	4	6	8
%	2.6	4.9	10.7	5.3	8.0	11.1
AEC	1	2	5	3	3	5
%	1.3	2.5	6.6	4.0	4.0	6.9
APG	11	16	15	14	19	20
%	14.5	19.7	20.0	**18.7**	25.3	27.8
TA	---	---	1	2	---	---
%	---	---	1.3	2.6	---	----
CO	3	15	12	3	5	17
%	3.9	18.5	16.0	4.0	6.6	23.6
Total number of valid entries	76	81	75	75	75	72
Total (%)	100	100	100	100	100	100

The analysis by subject area also demonstrates 'ownership and locus of control' as the most frequently cited advantage for both Physicists and Engineers in the sample. 'Wealth creation' is also considered to be important for the Physicists (22.4 %) whereas it is 'attainment of personal goals' for the Engineers (18.7 %) followed by 'wealth creation' (17.3 %). However, the second and third responses to the question show that 'attainment of personal goals' is more important for the Engineers (25.3 % and 27.8% respectively) than 'wealth creation' as it is for Physicists (19. 7 % and 20 %). Further work on this question would require asking

the respondents to state three perceived advantages in the order of importance so that the relative significance of each advantage could be better examined. Again what these respondents do not identify as advantages is interesting and worthy of further investigation (see Part 2).

5.21 Perceived disadvantages of setting up a business

Question 20 asked the respondents to state three disadvantages that they might perceive in setting up a business. Again, Miles and Huberman's (1994) data coding technique was utilised in order to analyse the responses to this open-ended question. The following categories were created:

Table 5. 211 Perceived Disadvantages of Setting up a Business by Category

Category	**Code**
Lengthy commitment of time and extra effort	LCT
Hard work	LCT- HW
Time commitment	LCT-TC
Increased workload	LCT-IW
Restriction of academic work	LCT-RA
High level of stress	LCT-HLS
High responsibility	LCT-HR
Development costs	DC
Risk and uncertainty	RU
Uncertain business environments	RU- UBE
Financial risk	RU-FR
Failure	RU-F
Job insecurity	RU- JI
Lack of experience and knowledge	LEK
Lack of financial resources/support	LFR
Unfavourable conditions to balance family needs and concerns	UCF
Culturally based obstacles	CBO
Government regulations	CBO-GR
Academic culture	CBO- AC
Ethical considerations	EC

The frequencies for each category by gender were observed as follows:

Table 5. 212 Perceived Disadvantages of Setting up a Business by Sex of Respondent

Category	Male			Female		
	1st response	2nd response	3rd response	1st response	2nd response	3rd response
LCT	58	49	38	19	9	18
%	**50.0**	**40.1**	**34.0**	**51.4**	24.3	**56.3**
DC	3	6	7	----	---	1
%	2.5	5.0	6.2	----	----	3.1
RU	36	39	28	14	19	7
%	31.0	32.0	25.0	37.8	**51.4**	21.9
LEK	5	6	17	2	1	2
%	4.0	5.0	15.1	5.4	2.7	6.3
LFR	8	4	9	1	1	1
%	7.0	3.3	8.0	2.7	2.7	3.1
UCF	3	8	5	1	4	1
%	2.5	6.5	4.5	2.7	10.8	3.1
CBO	2	8	4	----	1	1
%	2.0	6.5	3.6	----	2.7	3.1
EC	1	2	4	---	2	1
%	1.0	1.6	3.6	---	5.4	3.1
Total number of valid entries	116	122	112	37	37	32
Total (%)	100	100	100	100	100	100

'Lengthy commitment of time and extra effort' is the main disadvantage perceived by both female (51.4 %) and male (50.0) respondents. The restriction of academic work is frequently cited under this category as an important aspect that deter male and female academics from engaging in any form of business start-up activity. 'Risk and uncertainty' is the second important disadvantage for both groups (37.8 % for female, 31.0 % for male). Female respondents show a difference in their second response to the question of perceived disadvantages. 'Risk and uncertainty' (51. 4%) appears to be as important as the 'lengthy commitment of time and effort' (51.4 %). 'Lack of business experience and knowledge' is a notably important disadvantage perceived by male respondents in their third response (15.1 %).

The frequencies for each category by subject area were observed as follows:

Table 5. 213 Perceived disadvantages of setting up a business by subject

Category	**Physics**			**Engineering**		
	1st response	2nd response	3rd response	1st response	2nd response	3rd response
LCT	40	28	31	39	29	24
%	**51.9**	**35.9**	**43.0**	**49.4**	**37.3**	**33.8**
DC	2	4	3	3	1	4
%	2.6	5.1	4.3	3.8	1.3	5.6
RU	26	33	17	27	26	21
%	**33.8**	**42.3**	**23.6**	**34.2**	**33.3**	**29.6**
LEK	3	2	6	3	4	7
%	3.9	2.6	8.3	3.8	5.1	9.9
LFR	1	3	6	4	6	4
%	1.3	3.8	8.3	5.0	7.7	5.6
UCF	2	2	1	1	6	3
%	2.6	2.6	1.4	1.3	7.7	4.2
CBO	3	4	6	---	2	4
%	3.9	5.1	8.3	---	2.5	5.6
EC	---	2	2	2	4	4
%	----	2.6	2.8	2.5	5.1	5.6
Total number of valid entries	77	78	72	79	78	71
Total (%)	100	100	100	100	100	100

The examination of the perceived disadvantages by subject area illustrates a similarity between members of the two disciplines and also with the analysis by gender. 'Lengthy commitment of time and extra effort' is the most frequently observed factor that discourages Physics (49.4 %) and Engineering (51.9) respondents of the sample. This is followed by 'risk and uncertainty' for both groups (33.8 % for Physics and 34.2 for Engineers). Financial risk and job insecurity are the major subcategories observed in this study for both subject groups. Interestingly, relative to the other perceived disadvantages 'lack of experience and knowledge' and 'culturally based obstacles' do not appear to be crucial according to these findings. This contradicts the findings of the qualitative

survey (Part 2), which suggests that these are significant areas to explore further in face to face interviews.

5.3 Part Two: Qualitative Survey

5.31 Introduction to qualitative survey

The second part of this research addressed the following questions by using qualitative research techniques:

- What is the nature of the process of technology transfer as experienced by female and male physicists and engineers (i.e., how an idea with potential for technology transfer is identified, developed and moved into incubation)?
- Are there any gender differences in the process?

Method

A wide range of physicists and engineers at Southampton, Bath and Cambridge universities were contacted, initially by email, and asked if they would be willing to participate in a focus group or an interview (see list – appendix). In the light of the research questions two particular groups were targeted; women physicists and engineers at a range of stages in their careers who may or may not have been involved in commercialisation, and physicists and engineers who had been directly involved in technology transfer.

Two focus groups were conducted. The first consisted of ten physicists and engineers from Southampton University, seven of whom were PhD students and three of whom were postdoctoral researchers and (a different) seven of whom were men whilst three were women. The second focus group consisted of five physicists and engineers from Southampton University, four of whom were women and one of whom was a man. Three held permanent posts, the others held fixed term postdoctoral research posts. In both focus groups, one participant had set up a small business or spin out company. Others had varying degrees of experience

with different aspects of commercialisation (such as patenting, industrially sponsored and/or commercially applicable research).

Following these focus groups, eight in depth semi-structured interviews with academics from across the three universities were conducted. Five of these participants were at Southampton, one was at Bath, and were two at Cambridge. Overall there were four women and four men. Two participants (a women and a man) had fixed term research posts, the remaining six others either held or had held permanent academic posts. One had left academia and one had retired from academia; both worked full time for spin out companies. Two participants (both women) had no experience of technology transfer, all the other participants had been directly involved in spinning out a company or developing technology for licensing to a company. In addition, five technology transfer officers were interviewed; three at Southampton, one at Cambridge and one at Bath. Where possible, technology transfer officers directly responsible for facilitating commercialisation in physics and engineering schools and faculties within each of the three universities were interviewed.

Overview

The findings from this qualitative research reveal much about attitudes towards and experiences of technology transfer activity amongst academics in physics and engineering. The results highlight in particular the factors which both promote and inhibit involvement in such activities. The discussion of these data in section 5.32 has been structured in accordance with the key theoretical model utilised within this research project, which also informed the structure of most interviews, namely Ajzen's theory of planned behaviour considered in section 4 of this report.

Research findings from this part of the study also shed important new light on the relationship between opportunities for technology transfer within academia and gender distinctions and inequalities. These findings and their theoretical implications are discussed in section 5.34.

Furthermore, the qualitative data have produced some insights into the parenthesis of research objective one; namely to explore how an idea with potential for commercialisation is moved into incubation (see above). This question relates to the process and context of technology transfer. Based on interviews with academics and technology transfer officers, this report can comment on some general points in these areas. What was beyond the scope of this research was an in-depth investigation of, for instance, how decisions are taken about the form technology transfer should take on a case by case basis; how university policies relating to commercialisation are implemented and resources are channelled accordingly; or how relationships between technology transfer offices, investors and academic entrepreneurs are initiated, developed and maintained, etc. Since the commercialisation process is often complex and drawn out, such an examination would no doubt uncover the diversity of ways in which technology transfer actually occurs (from initial ideas to incubation) and uncover important differences in how commercialisation is managed, resourced and supported, across the three institutions. As a detailed study of these issues was not possible, this report will map general issues, which emerged as significant areas for further investigation in section 5.33.

Finally, it is worth noting that whilst most of the research participants for this part of the study were based at Southampton University, the issues and themes which form the main substance of this report emerged as recurrent themes within interviews with participants across all three universities.

5.32 Attitudes towards and experience of technology transfer amongst physicists and engineers interviewed

5.321 Behavioural beliefs

Behavioural beliefs constituted, in this case, beliefs about the likely outcomes of entrepreneurial behaviour, leading to favourable or unfavourable attitudes towards it. All the academics who participated in the research had a positive view of

entrepreneurship in general and academic entrepreneurship in particular. No one saw these activities as negative or bad, on the contrary, they were to be welcomed in broad terms. Six academics spoke specifically about the benefits resulting from academic entrepreneurship. Personal benefits consisted of an expanded sense of purpose and achievement, the chance to try out a different kind of career and the opportunity to make money. Other benefits to emerge from academic entrepreneurship were seen to inhere in its potential to generate wealth and employment, new funding opportunities for research and to ensure that academic research continues to produce outcomes which are relevant and useful to industry. Here the qualitative findings support the quantitative data in this study, discussed in section 5.12.

Two participants made the interesting point that academic research requires an approach, which transfers quite well to entrepreneurship, insofar as academic researchers are routinely involved in reviewing a given field of (research) activity and seeking out opportunities for innovation and funding within it. In the words of one of these participants,

> Running an academic research group in say a science or engineering department is a good training for entrepreneurship. You've got to run a small team, you've got to look for funding, you've got to look for ideas, you've got to beg and borrow resources because you don't have them. You've got to make things happen, you've got to provide leadership etc. So it's a pretty good training in being entrepreneurial, which I think is a very good thing about the university structure.

This positive stance on academic entrepreneurship incorporated a number of significant caveats however. Most participants argued strongly that so called 'blue sky' research, or research motivated by desire to further scientific understanding in a manner unconstrained by markets and profit incentives is a very important part of what universities do. Over half the participants commented that they were more interested in conducting blue sky research than more commercially applicable research, even though they also recognised the importance of making academic research relevant to industry. Conversely, only one participant claimed to have always been more interested in the applied side of research. Another two felt that academic research in physics and engineering ought to be made more

commercially applicable. Several participants emphasized that the choice to be involved in commercialisation activity should be an individual one, not one which should be imposed on academics. Such an expectation would not only be entirely unrealistic because of the already heavy workload academics endure, it would also potentially endanger the capacity and commitment of universities to carrying out blue sky research. For instance one participant felt that academic entrepreneurship is

> a very good thing if done properly. So if the academics involved are enthusiastic about it, if it's a good idea, then yes. … But I don't think that should be at the expense of people who actually don't want to do it, and are doing good scientific or other work. And indeed teaching is very important as well. So I think it mustn't be allowed to swing too far in the direction of 'if you're not entrepreneurial then you're useless', which is sometimes the impression I get.

Finally, six participants made the fundamental point that certain areas of research are more conducive to commercialisation than others. For instance, optoelectronics has far more commercial application than astrophysics. Opportunities for getting involved in commercialisation are largely dependent on the field of physics and engineering in which a researcher works. Thus attitudes towards commercialisation are to a certain extent constrained by whether it is possible within the particular field of physics within which academics work.

5.322 Normative beliefs

Normative beliefs are beliefs about the expectations of others, and the desire to go along with these expectations. In most cases, academics did not agree that there was any particularly strong expectation that they should engage in commercialisation activity. Rather, academics spoke of the pressure to generate research funding, in the form of either government or commercial grants and/or sponsorship depending on the area of research. The choice to engage in academic entrepreneurship tended to be seen as up to the individual, or more probably the team of researchers involved in the development of a particular technology with commercial application. However, a couple of participants noted that commercialisation activity was increasingly seen as something which academics were encouraged to engage in by universities. One mentioned that

commercialisation was coming to be seen as the fourth arm of an academic's duties, after research, teaching and administration.

Participants did not refer to any expectation to be entrepreneurial from family and friends outside academic circles. Where family and friends were mentioned, they were discussed as being in a supportive role vis-à-vis the participant's commercialisation activities, but not a guiding, inspiring or motivating one. Of far more significance were academic role models. Several of the academics who had been directly involved in spinning out companies spoke of the particular academic entrepreneurs who had inspired them to follow in the same track. For one this was a university tutor at undergraduate level who had spun out his own company, for another it was class mates from university who had gone on to establish their own businesses, for several others it was the head of the Optoelectronics Research Centre (ORC) at Southampton University who is a well known academic entrepreneur. Of similar importance was the organisational context in which academics worked. The ORC in particular was described by several participants as a context in which commercialisation was both encouraged and supported on the one hand, and highly feasible on the other, because of the nature of field itself. Optoelectronics is a fast moving field within physics, which attracts large amounts of commercial funding, thereby reducing the centre's reliance on teaching as a way of generating income and enabling researchers to work full time on their research and consolidate their industrial contacts. The ORC generates just over half the total number of Southampton university's patents. The environment itself is therefore highly enabling to potential academic entrepreneurs and this was recognised by all participants who were based at the centre.

5.323 Control beliefs

Control beliefs are ideas about what might help or hinder an academic from engaging in entrepreneurial activity, in particular, perceptions of how easy this would be and how much control could be exerted over it. In relation to such beliefs, participants in research discussed in detail a number of factors. Firstly, stage of career was seen by almost everyone as an important issue.: whilst the

entrepreneurial activities in which participants had been involved were always developed by a team, this team had in all cases been led or dominated by a senior academic (usually a professor), particularly in the early stages of commercialisation. Senior academics are seen as far better placed than junior academics or postdoctoral researchers to negotiate with investors and venture capitalists, who often view a track record of patents as an indication of reliability and commitment to the business idea. They are also better positioned to negotiate with their own department or school and the university more broadly. Furthermore, researchers and academics at an early stage in their career are under considerable pressure to consolidate a track record of research, whilst senior academics have usually already done this and although they too must continue publishing, they can afford to devote attention to other activities, such as commercialisation. Senior and junior academics agreed that setting up a spin-out company was not a viable option for postdoctoral researchers who wished to stay in academia but who had yet to secure a permanent academic position, since all their available time needed to be reserved for building up their publication record. Thus a postdoctoral researcher taking on the usual risks associated with setting up a spin out company also risks their future academic career if they fail to publish research. Neither of the postdoctoral researchers interviewed could envisage themselves starting their own business prior to gaining a permanent academic post. Researchers (postdoctoral or otherwise) who do not wish to stay in academia might be more likely to opt for working full time for a spin out company, as indeed one research participant did. However, this person also made clear that the risks associated with spin out creation, particularly the knowledge that the venture may well fail, made this a highly stressful, difficult and traumatic career decision. Other research participants noted that those with dependents are unlikely to choose this option, a point we return to in section 5.34.

A second issue related to various difficulties associated with dealing with the business world and bringing academic and commercial practices, assumptions and cultures together. Raising investment funds for a fledgling company can be exceptionally difficult, as a couple of participants with direct experience of this

activity pointed out. Even after initial investment has been granted, academic entrepreneurs continue to negotiate with venture capitalists over how to grow the company and who to appoint as its business leaders. All of these activities require an understanding of, and direct engagement with, commercial ideas and practices which are quite different to those within academia, and thus likely to be unfamiliar to the would be academic entrepreneur. In the words of one participant, "there's a new language you have to learn". Participants with direct experience of technology transfer argued that academic ignorance of business incentives and ways of doing things was a hindrance to the commercialisation process. In one case for instance, the academics' ignorance of how to write and present a convincing business plan to venture capitalists meant that initial attempts to secure investment failed. The reason a second attempt at a later stage was successful was because the academic leading the venture put significant time and effort into learning business presentation skills. A couple of participants highlighted that venture capitalists have ways of operating which may seem brutal and harsh to academics, and that academics need to understand this and get used to it if they are committed to the spin-out commercialisation route.

A third area of beliefs about what might help or hinder commercialisation related incentives and rewards within the academic career structure. Many participants commented that the academic career path conventionally rewards those who are successful in producing publications, not those who are involved in technology transfer. Some saw this as an active disincentive to commercialise research, whilst others remarked that in many cases academics are so concerned to maintain their publications record that they have little time to pursue other activities. The pressure on academics to uphold the requirements of research assessment makes it difficult to combine with involvement in a start up company, since both activities are highly time-consuming and absorbing. A related issue discussed by many participants was the difficulty of juggling publishing and patenting. The requirement that academics publish their research is based on a principle of free and open exchange of knowledge, ideas and expertise. This is sometimes in direct conflict with the need, within the business sector, *not* to share research freely, but

to protect financial investment in the commercial potential of new research by keeping it secret or claiming exclusive ownership of it through the patenting procedure. Two participants who worked in a spin out company described this conflict as frustrating. As one remarked, this issue is "the thing I find most difficult to cope with as an academic. For most of my career, openness and the free exchange of ideas is what science is all about, whereas if you've got an idea…commercially you have to keep it quiet and sit on it."

5.324 Summary

The study revealed a range of factors which are likely to influence academics' intentions to become involved in technology transfer and academic entrepreneurship. The relevance of these factors and how they interconnect will vary from case to case, shaping individual intentions in different ways. Across the range of participants in research, the study found a generally favourable view of (academic) entrepreneurship, which was felt to bring various economic and social benefits. Nevertheless, participants did not feel that there should be any formal expectation for academics to become involved in technology transfer. They also remarked that the degree to which engagement in commercialisation is possible depends to a large extent on the field of physics or engineering, as some areas have far more commercial application than others. Academic participants tended not to feel that there was any overt pressure to become involved in technology transfer. However, those who were involved had often been encouraged by role models or by the context in which they worked where commercialisation activities were supported. Finally, participants recognised that the relative ease or difficulty of engaging in technology transfer was determined to a large degree by the individual's stage in his or her academic career, the difficulties of combining academic and business demands and priorities, and the lack of formal rewards for commercialisation activities within the academic career structure.

5.33 Process and Context

5.331 Technology transfer: processes

In accordance with commitments to fostering commercialisation and entrepreneurship as well as research and teaching within their respective institutions, Southampton, Bath and Cambridge universities each provide a range services which aid and structure technology transfer activities. In each case these consist of a team of technology transfer officers dedicated full time to facilitating the administrative and legal aspects of patenting, licensing and spin out creation. These teams also provide or support a series of training and networking opportunities. At Southampton, this provision is coordinated by the Centre for Enterprise and Innovation, at Bath by Research and Innovation Services and at Cambridge by Cambridge Enterprise.[7]

Interviews were conducted with three technology transfer officers from Southampton, one from Bath and one from Cambridge. These participants were asked to describe their roles in relation to technology transfer resulting from academic research. There were no major differences in responses to this question from participants at the three institutions. Each provided a general overview of the technology transfer process, which might be summarised as follows:

5.3311 Initial contact

Academics with an idea for commercialisation approach the technology transfer office, where they are usually referred to the officer/s who deal/s with commercialisation across their academic faculty or school. In most cases, technology transfer is self-selecting in this manner; the academic comes to the technology transfer office, and not vice versa. This is because of pressures on time and resources, particularly amongst technology transfer officers responsible for physics and engineering faculties, as these comprise research areas with strong commercial potential.

[7] The web sites of these centres are as follows: http://www.cei.soton.ac.uk, http://bath.ac.uk/researchandinnovation/services/rid/index.html, http://www.enterprise.cam.ac.uk/about/about.html.

5.3312 Patenting

The technology transfer officer will research, advise, and assist, the process of securing Intellectual Property Rights (IPR) to the new research or technology. There are some cases in which the university does not have these rights, but in cases in which the research has been conducted by the academic as part of their post, the university does own the IPR. Filing a patent application is an investment in the new research costing upwards of £5,000. Therefore technology transfer officers have the role of evaluating the potential future benefits to arise from this investment. This stage of assessment can be long-winded, since it requires conducting research into the market for the technology as well as collaborating with the academic. At the point of filing the patent application, the technology transfer officers and the academic will ideally have thought through and agreed a suitable route for commercialisation, whether this involves spin out or licensing. Once the patent has been granted (for between 17 and 20 years), there are strong incentives to hasten commercialisation, since the patent is most likely to attract investment early in its life, and the costs of maintaining patents are high.

5.3313 Licensing

This commercialisation route is usually adopted in cases where the new research or technology adds to or improves a product which already exists in the market. It is the process whereby the university, as owner of the IPR of new academic research or technology, grants specific rights to a company to use it. This is usually in return for a royalty, such as a share of sales, which is then shared between the individual academic and the university.

Ideally the technology transfer officers and academics will work together to identify potential licensees. The academic may already have an in-depth knowledge of the market and companies that are most likely to be interested in the commercial applications of his or her research. In addition, technology transfer officers may undertake to research the market themselves (through searching

specialist databases and web sites) or may recruit specialist consultants to do so. Once a licensee has been identified, the technology transfer officers will help write a formally binding legal agreement between the various parties.

5.3314 Spin out

This commercialisation route is best applied in cases where academic research has produced an entirely new or 'breakthrough' technology, significantly distinctive from what is currently available within the market. In this scenario, technology transfer officers will oversee or facilitate the creation of a new spin out company, to which the university licenses the IPR. In effect, the university views its IPR as a share in the company.

Technology transfer officers emphasized that for this commercialisation route to be successful, the academic/s need/s to be highly committed to it, and prepared to devote a significant amount of their time to it. Typically, technology transfer officers and academics work together to attract investment funding to assist in development of the company such that it can work towards beginning to trade its product, and if successful, go to flotation. This funding may come in various forms, such as seed funding, venture capitalist investment, industry funding from large corporations or funding for postdoctoral researchers to work on the research and development of the product. The university may hire its laboratories or specialist equipment to the company for a negotiated fee.

5.332 Academic entrepreneurs

Of the academics interviewed, four had been directly involved in creating four (separate) spin out companies and two had negotiated a licence agreement with a company. Academic participants' descriptions of the basic stages of both of these commercialisation routes more or less matched those outlined above. In other words, at a fundamental level academics' perceptions of what these processes entailed matched those of technology transfer officers. However, what was clear from talking to academic participants (who spoke their specific experience of technology transfer rather than a general model of how it occurs) was that the

different stages summarised above can occur over highly varied time scales, can encounter different kinds of obstacles in relation to investment, and can have radically different rates of success, (where success is gauged by how much wealth or employment is generated). For instance, one of the four spin out companies had been, in the words of the academic entrepreneur associated with it, "a roaring success". The development of this company was rapid; it was set up in 2002 and was valued at just under £50 million when it floated on the Alternative Investment Market in the spring of 2004. The other three spin out companies had more modest success rates. Although none had been floated, they had all been successful enough in generating investment and funding to employ several business management staff and support a research team. This investment had come in different forms; in one case the founders of the company had invested some of their own funding into the company when it was created in the mid 1990's. In another case the academic entrepreneur who founded the company had secured government funding to support postdoctoral researchers and gone on to undertake R+D work for large corporations to generate income to support patent applications. The other companies had won seed funding from university supported competitions in the early stages and gone on to secure investment from a venture capitalist company.

The two academics with experience of the licensing route had reached an agreement with the company whereby it had the right to sell and develop technology invented by the academics, in return for a 10% royalty on sales. This was the most recent agreement in collaboration with the company that had lasted over ten years and undergone various shifts in that time. The enduring nature of this relationship between the academic researchers and the company was attributed in part to the nature of the technology itself, which was unusual in that 'pure' research of this technology carried out by scientists for academic purposes had produced fairly immediate commercial applications, which did not require extensive development or investment before being ready for the market.

5.333 Contexts: areas for further investigation

In addition to researching the processes of technology transfer, this study also identified a series of contextual factors which have an important bearing on how technology transfer occurs. As explained in the introduction to Part Two (section 5.31), these areas could not be researched in depth here, but would be fruitful issues to explore further within a more detailed, long term study.

- How do technology transfer offices prioritise technology transfer opportunities in practice? This relates directly to how universities define the purpose of technology transfer. At a broad policy level, universities may define technology transfer as an activity which brings about a spectrum of benefits, some expressly financial (such as raising money for the university), some social (such as seeking to make academic research relevant and useful to the local or global community, seeking to foster 'social IP', etc.) . However, at a day-to-day level technology transfer officers have limited time and funds, and have to prioritise and make decisions about which projects to support. These decisions will be informed by managerial perceptions of what kinds of benefits are most desirable. Thus the priorities, which guide the decisions of technology transfer offices, and the manner in which university policy on technology transfer is implemented, are worthy of further examination.
- How is the form of technology transfer agreed? Whilst there are general principles of whether to pursue a licensing or spin out route, in practice academics and technology transfer officers do not always agree which is best, particularly as they potentially represent different kinds of interests. It is possible to envisage a scenario in which academics may be concerned about the level of commitment and risk associated with spin outs and thus highly reluctant to pursue that route, whilst technology transfer officers may favour it because of the potentially much greater financial benefits for the university. An exploration of how decisions are reached about the form of commercialisation on a case-by case basis would provide useful insights into the process.
- How 'proactive' is the technology transfer office? In other words, do technology transfer officers see their key role as offering advice to academic entrepreneurs, or as negotiating on their behalf? Some of the academic

entrepreneurs interviewed felt strongly that the advisory role would be far more useful than the proactive role they had encountered. This is undoubtedly a highly difficult balance to strike, and therefore one worth researching further precisely to find out which kinds of roles work best for academics.

- How does the university evaluate the value of IPR, and therefore its share in spin out companies? This is another controversial area. One academic entrepreneur stated that British universities drastically over-estimate the value of the IPR, sufficiently so to discourage academics from becoming involved in creating new companies. Further research could establish the extent to which this is the case.
- What is the impact of long term agreements with venture capital firms? The Centre for Enterprise and Innovation at Southampton University has a contract with investment firm IP2IPO in which the firm has first refusal to invest in any company spun out from the university. Cambridge Enterprise, by contrast, has always resisted forming such agreements, and works with a number of different investment firms. Bath university is currently in talks with IP2IPO. The existence or non-existence of such agreements is likely to constrain and enable spin out creation in different ways, which could be clarified with further research.
- How is the use of university space and equipment negotiated? Technology transfer officers and academic entrepreneurs interviewed in this study acknowledged that this is a difficult issue to navigate, since new companies are potentially in competition with other academics and students for resources. A more detailed investigation could gather insights into how these conflicts arise and the extent to which workable solutions are possible.

5.334 Summary

This study found strong similarities across the three institutions as to the basic process of technology transfer. In the first instance, the new invention, technology, knowledge or innovation should be protected, usually through patenting. Technology transfer officers will then work with academic entrepreneurs towards commercialisation, which may take place through licensing or through the spin out

creation, depending on what is most appropriate. This process – and the different stages within it – can take place over highly varied timescales and technology transfer can have radically different rates of success in its potential to create wealth and employment.

This study also uncovered a range of factors which further constrain and define the ways in which commercialisation activities occur within different institutional contexts. These pertain to the ways in which the aims and objectives of technology transfer are defined and implemented in practice, the kinds of contacts and/or agreements that exist between technology transfer offices and the business and investment sector, and how universities define their relationship to, and stake in, newly spun out companies. These are all issues worthy of further investigation.

5.34 Gender and Technology Transfer

All participants in interviews and focus groups were asked to comment on why there are so few women involved in technology transfer in physics and engineering subjects. Participants responded with two basic explanations for this phenomenon. Firstly, the paucity of women physicists and engineers involved in technology transfer was felt to reflect the lack of women holding academic posts within physics and engineering more generally. All participants agreed on this point. Secondly, some participants viewed (academic) entrepreneurship as an activity which appealed to men more than women; they saw entrepreneurship as an inherently 'male' activity. This section of the report will review and assess both of these claims.

5.341 <u>The lack of women in academic posts in physics and engineering</u>

The majority of participants (academics and technology transfer officers) agreed that there is nothing particular to technology transfer or commercialisation activities per se which might exclude women or operate as a disincentive to their involvement. On this basis, the question to be answered is why there are so few

women in academic jobs in physics and engineering more generally. The possible reasons for this are complex, and are the subject of much research considered in the literature review of this report (see section 3.1). They encompass the education system leading up to university, as well as more pervasive gender stereotypes which constrain the ways in which men and women make choices about career and employment. Some participants commented on these areas. A female physicist for example noted that her school neither encouraged her interest in physics, nor praised her high achievement in this subject.[8]

However, whilst some participants recognised that conservative gender distinctions were part of the picture, many more emphasized that the demands of an academic career are not always that easily balanced with caring obligations outside work. Since the latter are conventionally women's responsibility, women are likely to experience more difficulty in pursuing an academic career. For instance, two participants – both young women at postdoctoral stage in their careers – remarked that being in a male dominated subject is unlikely to be discouraging for women in physics or engineering at degree level and above, since by that stage women have adjusted to the fact that they are in a minority and found ways of dealing with it. They felt that from postdoctoral level onwards, the difficulty for women is more likely to be in achieving a balance between academic career and family.

The reasons why this balance might be particularly difficult to manage within academia were suggested by several participants, who remarked that a university career makes huge demands on academics, particularly in the early stages following the completion of a doctorate. At this stage there are acute pressures to build up a record of publications, which is the only route to (but no guarantee of) an academic job. As one participant remarked,

[8] This issue is discussed further in the 2002 report 'Women Physicists Speak', published by the International Union of Pure and Applied Physics. The report is hosted at http://www.awise.org.

> The permanent jobs are so elusive. There are so few of them. [People who get these posts] seem to be the people who, you know…they don't sleep, they just write papers. And that's all they do… you really can't compete unless you're like that.

Apart from the rare instances of securing a permanent appointment soon after PhD completion, the more frequent option for physicists and engineers looking to remain within academia is to find work as a postdoctoral researcher. This work is typically on temporary contract, and may well demand a high level of flexibility (e.g., researchers may need to move around the country to be available for such contracts). The high pressure to produce a track record of publication, coupled with the necessity of geographic flexibility is not conducive to people (men or women) with family commitments. But given the tendency for women to be more heavily involved in caring and/or child care responsibilities than men, these conditions are likely to be more acutely difficult for women. As one participant noted,

> The whole of UK science funding is based around this idea of…an apprenticeship which is a series of postdocs, maybe if you're lucky – enough papers – you'll get taken on into a post. And its desperately competitive to get taken on if you're not 100%, 110% out there. You know, it's difficult to be the candidate who says, "well I took five years off because I had a family.

Thus physicists and engineers who take time out from their academic career care for children or other relatives (who are more likely to be women than men) before securing a permanent appointment are in a very vulnerable position. At the same time, those who gain secure academic posts prior to taking time out of work to take on caring obligations are also likely to be promoted at slower rates than colleagues. For instance, one female physicist acknowledged that having two children had slowed down her career. Another participant noted that, of the people she knew as a physics undergraduate,

> out of the women…the one that has gone the furthest, she concentrated on just writing papers, getting on in that sense, and although she's got three children, her husband had to do an awful lot of sorting out the children, and she only got her chair by concentrating just on doing the academic thing, ticking the right boxes that way.

It is therefore apparent from the responses of participants in this study that the career structure within universities rewards academics that pursue their research and teaching full time, and don't take time off to care for family members. As

women are more likely to be carers within families, these conditions tend to favour men rather than women. In effect, this system renders child care and other family commitments a 'personal' rather than an 'organisational' problem; the issue of balancing career and family is by default a matter for the individual academic to resolve.[9] It is significant that some of the female participants in this study had internalised the view that having children was a personal choice creating difficulties which it was the responsibility of the individual (usually the female academic) to manage. However, such perceptions are not particularly surprising given the lack of direct or explicit measures on the part of higher education institutions to counteract this form of organisational exclusion, as discussed in the IUPAP report 'Women Physicists Speak' (2002).

These findings have several implications. Firstly, the gender inequalities produced by the structure of academic careers are clearly not specific to physics and engineering subjects but exist in many other disciplines too. However, the obstacles created by the demands of academic work are very likely to exacerbate the pre-existing gender imbalance within physics and engineering. The findings from this report suggest that they may function to discourage and prevent women from (1) gaining a first permanent academic appointment and (2) progressing to more senior academic positions. These circumstances have a further impact on women's ability to engage in technology transfer. As has already been demonstrated in section 5.323, it is usually the more senior academics who are able to devote their time to technology transfer activity. If there is a tendency for women in physics and engineering to be concentrated at more junior academic positions (including postdoctoral research posts), they are less likely to be involved in commercialisation. Secondly, women physicists and engineers who do have caring obligations outside work are less likely to have the time to invest in commercialisation activity, where they are already struggling to balance the

[9] For further theoretical debates on the ways in which organisations reproduce forms of gender exclusion and discrimination, see Gheradi (1995) Alvesson and Billing (1997), Ross-Smith and Kornberger (2004) and Smithson and Stokoe (2005). See also 'Women Physicists Speak' (2002) hosted at http://www.awise.org

demands of family responsibilities and an academic career. In the words of one participant,

> Some women in academic research have family commitments and maybe can't go off at five o'clock to spend another couple of hours in an industry meeting when they've just finished their day's work. So the time juggling for women is more difficult…they're already doing two things at once.

5.342 Academic entrepreneurship as a 'male' activity

The other explanation for the lack of women in technology transfer in physics and engineering provided by participants was that for various reasons commercialisation and entrepreneurial activity were more likely to appeal to men and less likely to appeal to women. For example, several male and female research participants remarked that traditionally, entrepreneurship skills were more 'male'. A female participant felt that women are less willing to take on the personal risk of setting up a business. A technology transfer officer remarked that women were perhaps less interested in making money than in bringing about social benefits, and thus less inclined to engage in academic entrepreneurship. A female academic entrepreneur suggested that venture capitalists are more likely to take "male bullshit" as an indication of personal drive, dynamism and motivation. She added, "When you start dealing with the city and looking at funding…you are in a very male dominated world. They take no prisoners. They can be a bit intimidating." This, she felt, might well discourage women from involvement in commercialisation. Finally, a male academic entrepreneur claimed that women tended not to possess the qualities which made a business successful.

> I think women are nicer. They're probably not so rough and tough. They're probably fairer. And in some companies you have to be very unfair. And you have to sack people at the drop of a hat. And you don't want compassion, you want the cut and thrust of business.

5.343 Summary

This study has uncovered two key issues which impact on women's involvement in technology transfer. The first relates to career structure within universities. The insecurity of postdoctoral positions, the necessity of producing a strong publication profile in order to gain a permanent post and the system of rewarding scholars who do not take time out to engage in caring obligations are all factors

which work to seriously disadvantage those who are most likely to be heavily engaged with family commitments, namely women. This tendency applies to many different academic subjects, but is likely to exacerbate the already low numbers of women in the fields of physics and engineering. The effect is that fewer women are gaining permanent academic posts and fewer women are being promoted to senior academic positions. This in turn makes their involvement in technology transfer and academic entrepreneurship less likely and less feasible. The second key finding was that stereotypically gendered ideas permeate perceptions of entrepreneurship; it was seen by some participants as a male activity, or one more likely to appeal to men. These assumptions may have an impact on women's involvement in commercialisation. However the precise nature and extent of that impact requires further examination.

6. Conclusions and recommendations for further research

This pilot study explored the extent and process of women's involvement in science and technology transfer activities from physics, physics-related, and engineering departments within the three Russell Group universities in the UK. Viewing the engagement in academic entrepreneurship via technology transfer as a complex phenomenon, which is a function of the interrelated factors such as attitudes towards business start-up, social norms and perceived feasibility that impact on academics' motivation and intention, we combined quantitative and qualitative research techniques to address the research questions. While the quantitative study provided us with a general view of scientists' engagement in business start-up, the qualitative study enabled us to explore the subtleties and differences in engagement in technology transfer with a more detailed understanding of the socio-cultural milieu.

On the basis of the TPB questionnaire, two focus groups and a total of thirteen interviews with academics and technology transfer officers; this study has produced a range of key findings. Firstly, it was evident that academics who

participated in this research had a generally positive view of academic entrepreneurship, which was seen to bring about various social and economic benefits, both to the individual academic entrepreneur and the broader community. These respondents tended to associate personal benefits with an expanded sense of purpose and achievement and the chance to try out a different career route, in addition to the opportunity to make money; whereas social benefits are perceived to have the potential for job creation and making use of academic research for the benefit of industry and society. However, academics felt that there should not be a formal requirement for them to engage in technology transfer, rather, it should be left to individual academics to choose whether or not to become involved. Most research participants did not feel that there was any such formal requirement in the present climate despite the growing recognition of commercialisation as the fourth activity after research, teaching and administration. Instead, academic entrepreneurs spoke of being inspired and encouraged to commercialise their research by key role models and supportive working environments. Therefore, if attitude towards entrepreneurship proves to be an important contributing factor to entrepreneurial intentions of physicists and engineers, it can be influenced by successful academic entrepreneurs as role models, policy makers and enterprise educators.

Secondly, the study has produced insights into a range of factors that constrain academics' involvement in technology transfer, many of which relate to the structure and trajectory of academic careers and differences between academic and commercial practices, assumptions and cultures. Some of these factors affect men and women alike. These include the difficulty of combining the different and potentially conflicting priorities associated with academia, on the one hand, and business on the other, the lack of formal reward for academics who are successfully involved in technology transfer, the pressures to publish which make it difficult for them at an early stage in their career to be fully committed to commercialisation and various perceived difficulties associated with dealing with the business world mainly deriving from unfamiliarity, lack of understanding and business knowledge and lack of entrepreneurial skills. There was also evidence to

suggest that this lack of understanding undermined personal confidence in their ability to engage in technology transfer activities though this finding was stronger in women that men. In addition to these factors, it is worth noting the degree to which engagement in commercialisation depends on the field of study. Optoelectronics, for example, appears to be more conducive to commercialisation of its research base.

An additional set of issues were identified that were felt to make women's involvement in technology transfer particularly difficult or unlikely. These related to the strenuous challenge of combining an academic career and caring commitments outside work - a problem most likely to be faced by women, particularly those at an early stage in their career. As a result it would seem that women are less likely to be in a position to engage in technology transfer activities. The study also found some stereotypically gendered perceptions of entrepreneurship that constructed it as more appealing to men, but further research is needed to determine how far such views actively discourage women academics from getting involved in commercialisation and/or entrepreneurship. One strand of this research might be to examine implicit career models, perceived flexibility in the pursuit of career goals and perceived cultural and structural constraints.

Finally, this research has found that the policies and institutional arrangements designed to facilitate technology transfer were similar across the three universities examined, particularly with respect to the role of technology transfer offices. However, a range of contextual factors were identified which are likely to further define and constrain the form, scope and process of technology transfer. These factors pertain to the ways in which the objectives of technology transfer are defined and implemented in practice, the kinds of contacts and forms of agreements that exist between technology transfer officers and the business and investment sector, and how universities define their relationship to and stake in, newly spun-out companies.

Limitations of the current research and recommendations for further work:

As these findings are the result of an exploratory pilot study, carried out with limited time and resources and are based on a relatively small sample of research participants, they should be regarded as provisional, rather than definitive. Nevertheless, the findings presented here are positive and encouraging. They suggest a number of areas for further investigation, which would enable confirmation and clarification of the conclusions reached at this stage. A future research project could build on this pilot study by;

1) Examining a larger sample of male and female physicists and engineers across a number of universities to test for significant differences in attitudes towards and experiences of technology transfer. This would enable further clarification of the kinds of factors which encourage and inhibit their involvement in technology transfer, and the extent to which these can be linked to gender norms and/or inequalities. There is also a need for further work on the survey instrument to improve reliability and robustness.
2) Analysing in more depth the role of technology transfer officers in facilitating commercialisation in line with university policies. The precise issues to be explored further were considered in detail in section 5.333.
3) Exploring a wider range of technology transfer activities in the field of physics and engineering. This pilot study has focused on processes of patenting, licensing and spin- out creation from universities. However, in its broadest sense, technology or knowledge transfer includes a wide spectrum of activities which involve other forms of collaboration and cooperation between academia and industry. An example might be industrially sponsored research centres and institutes such as the Institute for Manufacturing at the University of Cambridge. Expanding the range of technology transfer activities to be examined would enable comparison of the different forms it takes and further clarification of men's and women's roles within it.

4) Including physics-based companies in the research. We have not begun to look at engagement of female physicists in the wider industrial environment.
5) Investigating implicit career models, career goals, aspirations and plans and the bases of this e.g. the conventional route through research and publishing versus an innovative route that encompasses enterprise activity – the latter may be stimulated by personal past experience of enterprise and/or that of parents or family. This element should also investigate alternative career models that include greater flexibility
6) Investigating the relative capability of men and women in tech transfer and business venturing activity by taking a broader sample from industry and not solely the university sector.

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