Ambidextrous academics and persistence in knowledge exchange: new findings for the UK and their implications for HEI strategic management of collaborative R&D and related activities

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1 Introduction

In this paper we provide an in-depth analysis of the collaborative research and knowledge exchange activities of individual academics in UK universities. We use detailed cross-sectional data from two national surveys of all academics in all disciplines in all UK universities that were conducted in 2009 and 2015. We also analyse a unique panel dataset created by linking the two surveys. We use this analysis to inform the way in which universities may design and develop strategic policies to enhance the knowledge exchange activities of their staff and the impact this may have on business innovation.[1]

We adopt a broad definition of business innovation which goes beyond the application of technology in new products and processes. This enables us to consider a wide range of innovations including in business models, organisational practices marketing and design which accompany technology-driven innovation. These aspects have become increasingly important in official attempts, at national and international levels, to measure innovative capacity and performance.

In keeping with this broader view of innovation we analyse the collaborative research and knowledge exchange activities of academics in *all* disciplines. This enables us to go beyond the conventional emphasis on science, technology, engineering and mathematics (STEM) which has tended to dominate discussions of collaborative research and knowledge exchange. We consider knowledge exchange activity differences across five broad groups of disciplines. These are engineering and material sciences, physics and mathematics, medical sciences, arts and humanities and the social sciences. We thus provide a comparison both across STEM and non-STEM categories and within them and analyse the implications of the patterns which emerge for the design of strategic knowledge exchange policies in universities.

In considering knowledge exchange activities we locate collaborative research alongside a wide range of pathways through which academics engage with the private sector. We consider the frequency and importance of activities across 27 different pathways. We present data on these pathways separately, and (using principle component analysis) grouped into five broad categories: *training; meetings, consultancy and advice; collaborative research; commercial activities and services; and public engagement.* We consider both the extent to which individuals engage in more than one of these individual or groups of pathways and how those patterns very by discipline and by a wide range of personal and institutional characteristics. These include the age, gender, seniority and research motivation of individual academics as well as their success in obtaining external research grant funding and patterns of mobility and promotion between our survey years.

Our analysis makes four distinct contributions. First, we extend the recent approaches to university-industry relations that have focused on organisational ambidexterity to the notion of individual ambidexterity. By this we mean the ability of academics to span the claimed divide between research and commercialisation activities, as well as their ability to

[1] Our survey data includes interactions with the public and third sectors which will be the subject of separate analyses.

use combinations of the groups of knowledge exchange activities which we analyse. We argue that understanding the extent of existing individual ambidexterity has important implications for the development of strategies either to increase the number of such individuals or intensify their involvement in knowledge exchange.

Second, we use panel data to enable us to identify the determinants of engagement in activities in the second survey period using prior patterns of engagement. We thus contribute for the first time in the literature (as far as we are aware) an analysis of continuity in engagement by engagement type based on a large survey-based panel dataset covering several thousand academics in all disciplines.

Third, in analysing this data we draw out the distinctive characteristics and different forms of engagement of individuals in STEM and non-STEM subjects.

Fourth, we identify the key strategic policy implications for universities including the importance of supporting a wide range of knowledge exchange mechanisms across all subject areas.

This paper is organised as follows: after this introduction, section 2 describes the academic and policy research context; section 3 outlines the UK higher education system; section 4 analyses the state of research funding, knowledge exchange income and collaborative R&D in the UK: section 5 describes the two surveys of academics used in this study; section 6 uses a multivariate analysis to explain the determinants of academic involvement in collaborative research and other engagement activities; finally, the conclusions outline the implications for strategy and policy.

2 The Academic and Policy Research Context

In the UK, as elsewhere, there has recently been increased academic research and policy activity concerned with the extent, nature and effects of university-industry knowledge exchange including collaborative R&D (for excellent recent reviews see Perkmann et.al., 2013 and Bozeman et.al, 2013). The bulk of the early literature focussed on the USA and emphasised commercialization outcomes based on a narrow range of indicators, typically patenting, licensing and new business formation and their links in turn with innovation outcomes. It also focussed on the activities of science (especially life science), technology and engineering academics located in research intensive Higher Education Institutes (HEIs). An associated literature on campus management of these activities emphasised the role of Technology Transfer Offices and intermediating collaborative research organizations in facilitating collaborative R&D and commercialization routes to innovation. Much of this literature was framed within a hypothesized tension between the research motivations of academics and industry. At the level of the individual, the pursuit of fundamental understanding and public dissemination of findings of the former was contrasted with the pursuit of research applications for private gain by the latter. At the university level this was conceived as a conflict between twin objectives of research exploration and research exploitation.

More recent research, whilst still focussing on science based and engineering disciplines and research intensive HEIs, has adopted a wider perspective and has increasingly extended beyond the US. It has drawn increasingly on surveys of individual academics and collaborating businesses and has placed commercialization and collaborative R&D pathways within a wider range of formal and informal knowledge exchange activities. These multiple additional pathways have included people-based activities such as training and secondment, and problem-solving activities such as consultancy and contract research. Academics are frequently involved in several of these rather than specializing in one alone (Perkmann et al 2013, Hughes et. al. 2016). Moreover, knowledge exchange, including collaborative R&D and commercialization, may take place alongside or be informed by informal meetings and advice. Informality may extend to contractual commercialization and patenting occurring outwith the university structures and rules designed to promote or regulate it (Link et. al., 2007; Nilsson et.al.2010; Ponomariov and Boardman 2008; Fini et.al, 2010; Freitas et.al, 2013 Hughes et.al. 2016).

This more recent work has also emphasised a non-zero sum approach to fundamental research and external engagement activities. This is the case at the level the level of the HEI as a whole, and at the level of the individual. Thus, following the seminal work of Stokes 1997, one part of this literature has emphasised a naturally positive interplay between the pursuit of fundamental understanding and considerations of use. This literature has proceeded to analyse how peer group socialization may enhance this personal natural or complementary interplay, as well as how it may vary across disciplines and across groups of academics differentiated in terms of institution, age, gender and seniority. Seen from this point of view, excellence in research and involvement in external exploitation pathways may be complementary rather than in conflict (Bozeman and Gaughan 2007; Bercovitz and Feldman 2008; D'Este and Perkmann 2011; Caloghirou et.al.2001; Grimpe and Fier, 2010; Lin and Bozeman, 2006; Tartari et.al, 2014; Stuart and Ding, 2006; Kenney and Goe, 2004; Martinelli et.al, 2011; Hewitt-Dundas, 2012).

The public policy and HEI impact strategy debate has revolved around the creation of incentives and structures to ameliorate the tension or enhance the complementarity (Bozeman et al, 2015; Link and Siegel, 2005; Ponomariov, 2008; Bruneel et.al.,2010; Renault, 2006; Ponomariov and Boardman, 2010; Siegel et.al, 2003a, 2003b; Gaughan and Corley, 2010; Bozeman, 2000; Boardman and Ponomariov, 2007; Clark ,2011; Lee, 2000).

One part of this literature has maintained that a natural tension at the individual persists but that "*organisational ambidexterity*" to manage it can be achieved through, for example, TTOs and collaborative research centres as part of a system of dual university structures (Sengupta and Ray, 2017 and Chang et.al., 2009). These exploitation structures allow a focus on exploration and allow specialization by groups of academics working within them to coexist with the usual faculty structures less directly concerned with exploitation (Ambos et.al., 2008). It has also been argued that historically HEI systems in different countries and periods have evolved functionally with different HEI "species" developing different emphases on teaching research and external impact (Martin 2012). In that sense HEI systems as a whole may display different degrees of ambidexterity depending upon the variation in species within them.

There is ample evidence that academics engage in collaborative and other forms of external activity for positive research reasons (e.g to enhance their access to research resources, to enhance their academic reputation, and to gain new research insights (Perkmann et.al. 2013; Hughes and Kitson 2012; Hughes et.al 2016; Bozeman et al 2013)). This is consistent with research suggesting that academics self-sort into distinctive engagement strategies. One group pursuing university enterprise links for instrumental academic research reasons is labelled “academic”, a second labelled “pioneer” adapts science to enterprise purposes, with a third pursuing a “Janus” like strategy alternating between the two (Shinn and Lamy 2006). This latter aspect can be related to separate research arguing that individuals manage conflicting tensions by adopting “hybrid role identities” with, for example, a focal academic self and a secondary commercial persona (Jain et. al. 2009). We find it useful to characterise individuals with these Janus like or hybrid personae as exhibiting a predisposition towards “*personal ambidexterity”.*

We argue in this paper that the efficient design and implementation of university or campus policy towards collaborative R&D and innovation based on HEI research must be rooted in an understanding of the characteristics, objectives and motivations of the academics who take part in them, the presence or absence of this personal ambidexterity and the factors which influence its prevalence.

We also argue that a continued focus on STEM subjects at the expense of analysing other disciplines in the arts and humanities and the social sciences omits an important aspect of knowledge exchange.

External engagement arising from the arts and social sciences can have an important role to play in innovative behaviour (Hughes et al 2011, 2013b; Bullock and Hughes 2016). Recent research on innovation measurement has taken an increasingly wide view of innovative activity. It recognises that the innovation process goes beyond the accessing and implementation of technological knowledge per se. The European Union Harmonised Community Innovation Survey (CIS) records the conventional technology based product and process innovation which have been the focus of most work on university contributions to innovation. This is proxied most frequently by measures of R&D, patenting and licensing and hi-tech start-ups. The CIS also measures innovation in terms of new forms of business organisation form and management practice including for example marketing and design practices which are far more widespread.[2] Whilst businesses report that the bulk of their expenditure on innovation expenditure is on internal R&D and the purchase of equipment of machinery, a substantial amount is marketing and design and training for innovation and Hughes et.al 2013c show these proportions are higher for larger firms.[3]

There is a concomitant demand from business from a much wider range of disciplinary inputs than STEM alone. In a representative national sample survey of over 2000 UK businesses the most frequently important subjects were, indeed, Engineering and Materials

[2] In the UK in 2015/6 around 19% and 13% of businesses reported technology-based product or process innovation respectively but 42% reported wider business model innovation. BIS 2016 Table 1 p.8 and Table 2 p.12.

[3] In the UK in 2015/6 marketing design and training accounted for 20% of all innovation related spend compared with 42% on internal R&D and 29% on plant and equipment BIS 2016 Figure 2 p.11.

Science, and Physics and Maths. However, 69% cited social science and arts and humanities disciplines amongst the most important disciplines for their business, a figure which rose to over 90% for larger business of which 30% placed importance on Business and Financial Studies and 36% on Arts and Humanities (Hughes et al, 2013c p.40). Around 50% of UK businesses are motivated to engage in knowledge exchange with university academics in Social Sciences in relation to Marketing and Sales Support and Human Resource Management. Moreover, in terms of support for innovation *per se* 47% accessed STEM academics alongside non-STEM disciplines (Hughes and Kitson 2012 Table 10 p741). It is clearly important in designing HEI strategy toward external collaboration to understand the interplay between STEM and other disciplines as well as the distinctive role of Non-STEM disciplines themselves. In this paper we therefore provide analyses of collaborative and other external research collaborations by STEM and non-STEM disciplines.

3 The UK HEI System and Policy Context

The UK HEI system is an important context in which to discuss these issues as there is widespread recognition of the international excellence of the academic research performance of the UK HEI sector (Elsevier 2017). There has, however, been continual concern in the UK that the social return to public support for research in terms of UK innovation and productivity performance has been less impressive. This concern has persisted despite estimates of returns of over 20% to such investment, evidence of public sector support "crowding in" private sector R&D (Haskel et. al. 2014; Scandura 2016) and numerous case-based estimates of the gains from such public support (Hughes and Martin, 2012).

Notwithstanding this evidence there have been over a dozen major policy reviews and reports on UK research funding and knowledge exchange in the last 5 years alone (Docherty et al., 2012; Heseltine, 2012; Wilson, 2012; House of Commons Science and Technology Committee, 2013; Witty, 2013; BIS, 2011 2014a 2014b 2014c 2014d; Hauser, 2010 2014; NCUB, 2014; Hughes 2015; Dowling, 2015; Nurse,2015; Stern 2016). This culminated in 2018 with a major structural shift in the organization of research support for universities with a stronger focus on translational and collaborative R&D. From 2018 a new integrated institution UK Research and Innovation (UKRI) will oversee a combined research budget of £8bn per annum by 2020, to cover direct funding for university research, knowledge exchange, and support for innovation more generally. This will include £1.7bn of new funding for collaborative university-industry research in specified "grand challenge" areas. This shift has been designed, within an overall industrial strategy, to raise collaborative and translational R&D but also to increase the equality of its geographical spread across the regions and devolved administrations of the UK (HMG 2017).

These developments represent a major strategic challenge for UK HEIs. They imply a significant intensification of the knowledge exchange activities of UK academic staff, and a redistribution across universities. This intensification means either increasing the commitment of those currently involved in exchange, and/or facilitating participation by those not involved. Regional redistribution poses new challenges for universities with currently low levels of staff engagement in collaborative R&D. Understanding current patterns of individual academic involvement in collaborative R&D and other engagement activities must, we argue, play a central role in the UK in the evolution of HEI strategy formulation.

The focus on the role of individual academics is central to this paper. In adopting this perspective we endorse the opinion expressed in a recent review that:

"In studies of research collaboration…..it is easy to lose sight of the fact that the objects are flesh and blood human beings pursuing multiple, complex and often conflicting motives."

(Bozeman et. al. 2013. p.38)

In this paper we put the "flesh and blood" human beings centre stage and locate them in their complex institutional settings. We use this to inform suggestions for the strategic design of policies to support collaborative R&D and related knowledge exchange activities. The empirical analysis we provide is based on two large national cross-sectional surveys of individual academics. These surveys addressed all university staff with research and or teaching roles in all disciplines in all HEIs in the UK university sector. The surveys provide, *inter alia*, information on the frequency, and geographical spread of individual academic involvement in 27 engagement activities with the public, private and third sectors.[4] The activities covered range across the full spectrum from commercialization (patenting licensing etc) through collaborative and contract research to training and secondment, and informal advice. Drawing on the two surveys allows us to construct a unique panel date set. The panel allows us to analyse the dynamics of engagement and in particular to characterize those academic who persist in collaborative R&D and other exchange pathways.

This analysis of persistence is particularly novel as it adds substantively to the existing literature by allowing the identification of factors which predispose academics to maintain long term engagement patterns. It also allows us to analyse the interrelationship over time of different pathways and how these pathways vary across different disciplines. We can reveal the extent to which individuals engage in groups of pathways and also whether engagement in one pathway (collaborative research) is linked to another (e.g commercialization) in a subsequent period and vice versa.

Understanding these patterns should be a central requirement in the design of HEI strategic policies to promote long term and sustained external relationships. Our analysis of these patterns covers all disciplines and all types of HEI from the largest most research intensive HEIs to specialist institutions in for example medical research agriculture and the performing arts. This allows us to draw out implications for strategy across the full range of UK HEIs.

In analysing these patterns, we consider how they are influenced by the discipline, research orientation, age, gender, and seniority of individual academics. This allows us, *inter alia*, to draw out the implications of our results for strategies to strengthen both STEM and non-STEM contributions to innovation and collaborative research. It also has implications for the related question of what are the appropriate new metrics for assessing and measuring the

[4] The third sector comprises voluntary community groups, social enterprises, charities, co-operatives and mutual organisations.

performance of universities in relation to their innovation ecosystems once we step beyond the realm of STEM?

4 Research Funding, Knowledge Exchange Income, and Collaborative R&D in the UK

The UK HEI system includes over 160 independent not-for-profit charitable institutions which receive central government funding for teaching and/or research. There is considerable heterogeneity in the sector in terms of disciplinary focus, research intensity age and mission. HEIs range from specialist institutions in the creative and performing arts to the 24 self selected research intensive universities of the Russell Group. Other groupings can be based on age of establishment with so-called “red-brick” and “plate glass” universities originating in periods of system expansion in the 1920s and 1960s respectively. The system also includes a large group of ‘post-1992’ universities which are former polytechnics that converted to university status in reforms enacted in 1992.

Public funding for research for these institutions is provided through a dual funding system (Hughes et.al., 2013a). This system consists first of a “forward looking” stream: this awards grants to individual researchers or research teams through peer reviewed open competitions. These are run by seven disciplinary based Research Councils some of which also maintain their own research centres.[5] These awards are increasingly expected to yield impact beyond the strictly academic and all bids must identify expected impact pathways. Research funding from this source amounted to £2.7bn in 2014. A second “backward looking” stream consists of quality related (QR) formula based block grants to universities to support research. These are awarded by the separate Higher Education Funding councils for England, Wales, Scotland and Northern Ireland.[6] These funds are augmented depending upon the extent to which an HEI attracts research funding from industry and charitable foundations. These QR funds amounted to around £1.6bn in 2014. They can be applied to support whichever disciplinary or inter-disciplinary research pattern the university wishes. Their amount is based on periodic assessment exercises which originally focussed on peer assessment of academic publications. In 2014 the exercise incorporated for the first time an assessment of wider socio-economic impact which was based upon an evaluation of “impact case studies”. The next exercise in 2020 will continue this evaluation process and will allocate approximately 33% of the total funding available to support research on the basis of excellence in wider impact effects.[7]

Both of these sources of support are highly concentrated amongst a small number of universities with very few entrants or exits from the top 10% in terms of research income. The top 10% of HEIs (consisting of 16 institutions which are all members of the Russell

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[5] These are the; Engineering and Physical Sciences Research Council (EPSRC); Economic and Social Research Council (ESRC); Arts and Humanities Research Council (AHRC); Scientific Technical Facilities Council (STFC); Natural Environmental Research Council (NERC); Biotechnology and Biological Sciences Research Council (BBSRC); and the Medical Research Council (MRC).

[6] These councils are the Higher Education Funding Councils for England (HEFCE) for Wales (HEFCW), and for Scotland (SFC). The equivalent functions in Northern Ireland provided through the Higher Education Division of the Northern Ireland Department for the Economy.

[7] In addition in England a specific third stream of funding to support knowledge transfer has been available to universities. This Higher Education Innovation Fund (HEIF) is committed against specified knowledge exchange strategies by individual universities and amounted to around £160m in 2014.

Group) accounted for 63% of all Research Council Funding in 2002 and 2010, 55% of QR allocations in 2002 and 53% in 2010 (Hughes et al 2013a). A dominant position which has been maintained to date.

The increasing importance given to impact in the dual funding system has been supported by a range of university-industry policies administered by Innovate UK[8] which amounted to £0.4bn in 2014. This included £173m specifically for collaborative R&D projects and a further £121m for joint university-industry Catapult Centres designed to accelerate the translation of research into applications. By 2015, UK HEIs were receiving around £950m in specific support for collaborative R&D from these and other sources.[9] This was the counterpart to approximately £340m in external non-public sector collaborative partner cash and "in kind" inputs into collaborative R&D.[10] Each of the dual funding streams and the support for collaborative research innovation and knowledge exchange will from 2018 be under the single roof of UKRI.

This funding for collaborative R&D can be set alongside other knowledge exchange related external income streams. These are shown in Figure 1 which presents both the total amount of each, and also the share in each of the Top 10% of HEIs ranked by total collaborative R&D income. Four of the streams show a heavy degree of concentration: the top 10% by total collaborative R&D account for 60% of collaborative R&D, 59% of contract research and 41% of IP income. Their role in CPD is somewhat less at 24% of income, and around 10% of regeneration and development income.

[Figure 1 here]

In the analysis which follows we disaggregate the UK HEI population into four groups to explore differences in knowledge exchange linked to institutional type and research intensity. The four groups are the top 10% in terms overall research funding from all sources combined; the post 1992 universities; specialist institutions; and older universities (i.e. Russell group universities outside the top 10% plus other pre-1992 universities).

5. The UK Survey Findings: Univariate Analysis

The data for this study is based on a survey of all academics working in UK universities in 2015 combined with a comparable survey of academics carried out in 2008/9. Both surveys were directed at all research or teaching active members of staff at UK HEIs: the 2008/9 survey had 22,170 completed questionnaires (a response rate of 17%) and the 2015 survey had 18,177 completed questionnaires (a response rate of 14%)[11].

[8] Innovate UK is the UK's Innovation Policy agency. It is a non-departmental public body formerly reporting to the Department for Business Energy and Industrial Strategy but now subsumed within UKRI.

[9] Collaborative R&D is defined for this purpose as projects with public funding from at least one public body and a material contribution in cash or kind from at least one non-academic collaborator. Contract research is defined as research funded to meet the specific research needs of external partners (excluding any separately reported collaborative R&D. (http://hesa/support/definitions/hebci

[10] HEFCE(2017) Data Tables HE-BCI Part B Tables 1.2.3.4c

[11] The Survey and Panel survey sample datasets are substantively free from response bias. For details of the response bias analyses see Hughes et.al 2016 and Lawson et.al 2016.

In this section we report the key results from the 2015 survey. The data from the 2008/9 survey is used in combination with 2015 data to form a panel of academics. The continuity of their engagement patterns is discussed in a multivariate context in the next section.

The large and representative sample size of the 2015 survey provides a robust picture of the UK research and knowledge exchange landscape. The surveys include data on work roles and their recognition by the university; the balance between basic and applied research; the range, depth and frequency of external knowledge exchange interactions and how they are initiated; and the motivations and constraints experienced by academics when engaging in knowledge exchange activities.

There is no publicly available database which provides contact details for the sampling frame. We therefore proceeded by compiling a list of all UK HEI from data compiled by the Higher Education Statistical Age (HESA), Universities, UK, the Higher Education Funding Councils of England, Wales, Scotland and the Northern Ireland Department for Employment and Learning. We then manually collected from the websites of all of these institutions a list of all academics active in teaching and/or research listed on the websites in all departments and faculties. This email directory was the sampling frame to which we addressed a web-based questionnaire. Staff at university-based research centres and related units were not included in the sampling frame as there was a large amount of duplication between departments and institutes. The 2015 survey instrument was administered using a proprietary survey design and implementation consultant. Because of the scale of the survey which was sent to over 140,000 academics identified in the sampling frame, the survey was conducted in a series of waves.

The Respondents

The survey asked respondents to select one of 36 disciplinary areas (corresponding to the units of assessment for the UK's Research Assessment Exercise) which have been further aggregated into six broad categories. Figure 2 shows the distribution of respondents by these broad subject categories: the social sciences represent the largest category followed by health sciences whereas engineering and materials science is the smallest category. This subject distribution corresponds to distribution across the academic population in the UK with the exception of arts and humanities which are slightly underrepresented in the survey.

[Figure 2 here]

Table 1 shows the survey responses according to position, gender, discipline and institution. Staff in teaching positions (lecturer, senior lecturer, reader or professor), which are normally permanent appointments, account for 73% of survey respondents; 18% of respondents work in research roles as research fellows; 3% are research or teaching assistants or technicians; 2% are employed as tutors or teaching fellows; and 4% of respondents hold emeritus or honorary posts following retirement. Only 42% of respondents are female and the gender imbalance is most apparent in engineering and material sciences (17% female) and mathematics and physics (24% female). There are also contrasts by institutional type.

To analyse institutional differences, we grouped UK universities into four broad types: the top decile in terms of research funding; other older universities formed pre-1992; newer universities formed post-1992 (primarily former polytechnics); and specialist institutions, of which there are 30 mainly with a focus on arts and media. As shown in Table 1, 35.8% of the respondents were from the top-decile institutions, 33.5% were from older universities, 27.5% were from younger universities and 3.2% were from specialist Institutions. The top decile and the older universities have higher shares of academics in the STEM subjects compared to the younger universities which have higher shares in the social sciences and the arts and humanities. Furthermore, the top decile and the older universities have higher shares of academics in senior positions compared to the younger universities. Furthermore, the proportion of staff employed as research fellows is five times higher in the top-decile institutions compared to the younger universities – indicative of the research focus of the former group

[Table 1 here]

To interpret subject, seniority, gender and institutional differences it is important to understand how these characteristics interact. For example, the distribution of seniority differs between disciplines and by gender - as women are on average in more junior positions compared to men. The share of research fellow positions is highest in science fields and lowest in arts and humanities and the social sciences. By contrast the share of respondents in lecturer positions is higher in these two fields. The share of women is also higher in health science and lowest in engineering and materials science. This needs to be kept in mind as it could mean that for example some of the gender, seniority and institutional differences found in the survey may be due to subject area variations. This pursued further in the multivariate analysis in the next section.

Research Motivation

The ability to engage with research users may be influenced by the type of research academics pursue. The conceptual framework we use is the Pasteur's quadrant approach advanced by Stokes (1997) - as shown in Figure 3. According to Stokes (1997), research can be motivated by a quest for fundamental understanding (pure basic research), or solely with application (pure applied research), or with both (user- inspired research), or with neither. The first three are referred to by Stokes (1997) as the Bohr, Edison and Pasteur quadrants, respectively Academics pursuing more applied, experimental or user-oriented research lines (Edison) may engage more with businesses as they may be more motivated by - and are better placed to address issues of - near to market applications. Academics motivated to pursue fundamental research may have fewer incentives - and fewer opportunities – to engage. However, basic and applied research efforts do not develop in isolation - problems encountered in applied research can feed back into basic research efforts and vice versa ('Pasteur' type researchers or in our nomenclature ambidextrous academics).

[Figure 3 here]

The results from the survey show that overall: 32% of research time is spent on basic research, 27% on user-inspired basic research and 41% on applied research. As shown in

Figure 4, the shares differ by disciplines and follow a pattern similar to the analysis in terms of primary motivation: in arts and humanities academics report spending 51% of their research time on basic research; in physics and mathematics the share is 44%. In contrast, those in the health sciences spend close to 60% of their research time on applied research; this share is more than 50% in the case of engineering and materials science; and 42% in the social sciences. Further evidence also shows that those who consider their work to be primarily applied still spend 8% of their research time on more basic research tasks and 17% on user-inspired basic research; those that primarily engage in basic research still spend on average 7% of their time on applied research and 11% on user-inspired basic research; finally, those that primarily identify their research as user-inspired spend 21.5% on pure basic research and 17% on applied research tasks. This represents a substantial degree of potential or actual ambidexterity at the individual level with researchers spanning the applied and basic quadrants as well as spending research time motivated by use per se.

[Figure 4 here]

Evidence from the survey also shows that those at post-1992 and specialist institutions spend considerably more time on applied research than those in the other older groups of universities, where more time is allocated to basic research. Much of this may be due to differences in subject area and staff composition. Specialist institutions, by definition, have a strong focus in either the arts or in life sciences. The newer institutions have a strong focus on social sciences and far fewer staff in hard sciences (less than 40% in STEM). They also employ far fewer research-only staff (just 7%) and the bulk of positions are at senior (or principal) lecturer level. By contrast, the top-decile of universities have a stronger focus on STEM with more than 60% of positions in these areas; and a third of respondents are employed on research-only contracts. These differences affect work and research activities but even after controlling for subject area and seniority institution, the differences remain significant. These differences are essential to bear in mind in designing strategies for knowledge exchange and collaborative research in different institutional settings.

Innovation and Knowledge Exchange

Discussions of the application and impact of research have largely focussed on commercial application in the science and engineering disciplines (STEM) through technology transfer mechanisms (patents, licenses and the formation of spin-out companies). The importance of these mechanisms, as shown in Table 2, varies significantly across industries and research fields. Moreover, income from these mechanisms account as we have shown earlier for a relatively small proportion of the external income of universities. They have, nevertheless, featured prominently in the assessment of their contribution to UK innovation capacity.

[Table 2 here]

As shown in Table 2, 22% of respondents in engineering and materials science have taken out a patent in the last three years; followed by just under 15% in biology, chemistry and veterinary science. As may be expected, there is a relatively low propensity to patent in social sciences and the arts and humanities. A very similar pattern emerges where research outputs had been licensed to a company and whether or not respondents had formed a spin-out company in the last three years. What the data show, however, is that while the social sciences and arts and humanities may have fewer opportunities appropriate for patenting, licensing and research-based spin-out formation, these mechanisms nonetheless occur in these disciplines.

It is important to note that the scale of commercialization revealed by the survey is much higher than implied by official aggregate statistics based on university administrative data. In terms of spin-offs the annual rate implied by the survey data is over 1300 compared with the official estimate for 2015/6 of 684 (HEFCE 2017). Similarly, even if we very conservatively assume only one patent filed by patent active respondent, the implied annual rate of patenting is over 2300 compared with the official estimate of 1219 for 2015/16 (HEFCE 2017). This tendency to bypass formal structures is consistent with studies for the US and elsewhere (Link et. al 2007; Fini et. al. 2010; Huyghe et. al.2016; Grimpe and Fier 2010; Perkmann et al, 2015). From a strategic university planning point of view, understanding the factors behind this and devising appropriate incentives for disclosure (or minimize the damage done by regulating it) is an important challenge.

The analysis of commercialisation activities by seniority and gender (as shown in Table 2) shows that men are more likely to report commercial involvement than women. Professors are also more commercially engaged than those in less senior positions. For example, almost 10% of men state that they took out a patent, compared to less than 4% of women; 11% of professors took out a patent compared to 3% of lecturers and 6% of research staff. As could be expected, the share of researchers involved in patenting is lowest for those that primarily motivated to work in basic research though even here some patenting occurs (4%). These patterns are similar across other commercialisation activities.

The differences in strategic focus between different institutional types will influence the type and extent of commercialisation activities. As shown in Table 2, academics in the top-decile and older universities are more likely to generate patents compared to newer universities and specialist institutions. Additionally, academics in older universities are more likely to license the outputs of their research. These contrasts may reflect the stronger STEM research focus at these institutions but there are two key issues that need to be stressed. First, the contrast across institutional types is not so apparent in terms of spin-outs and the formation of consultancies. Second, the focus on commercialisation and technology transfer does not capture all of the multiple mechanisms through which the engagement of academics may influence broader notions of innovation. David Willetts, a former UK Minister of State for Universities and Science has observed that university spin-outs 'get disproportionate attention' and 'that it 'can be counterproductive if universities become preoccupied with generating lots of start-ups, many of them too small and vulnerable to survive' (Willetts, 2017, p.271)

There is increasing recognition that the rich resources of the university can influence innovation in a variety of sectors through a range of pathways that are not restricted to commercialisation (Hughes and Kitson, 2012). The survey identified 27 non-commercialisation modes of interactions. These were initially grouped into three categories- people-based, problem-solving and community-based. The respondents were asked to indicate which of these modes of interactions they had actively used in the previous three years. People- based modes of interactions are concerned with networking and provision of education services to professional external organisations; problem-solving activities include joint and commissioned research; and community-based activities with exchanges with the general public and the voluntary and cultural sector**.**

People-based activities have long been a focus of public policy in the UK.[12] Figure 5 shows that there are very high levels of interactions with professional external organisations through people-based activities and especially through conferences, networks, and invited lectures. Almost 88% of respondents are involved in at least one of these activities (each is individually used by 55-80% of academics). This is followed by sitting on advisory boards, placing students with external organisations, and training employees for external organisations. A further 25% of respondents were involved in standard setting forums which are a crucial mechanism for shaping and developing pathways of innovation activity. Approximately 22% of the surveyed academics involve external organisations in curriculum development and around 7% provide enterprise education. This result indicates the significant extent to which conventional modes of academic interaction – such as the dissemination of research at conferences, the education of students and people exchange through work placements - are important forums for interactions with external organisations.

[Figure 5 here]

Respondents were also asked to indicate how important each activity was as a pathway to impact on a 5-point Likert scale - where 5 is very important and 1 is unimportant. On average all activities were rated as 'important' ranging from 3.5 to 4. This is not surprising, since if academics did not think they were important they would presumably not be willing to spend time doing them. The share of users who rate activities as 'very important', is indicated by a red triangle in Figure 5: this share is highest for participation in networks and invited lectures at around 30%. The lowest share of users considering activities as of high importance, were found for teaching based activities such as curriculum development, student placements and enterprise education (all at less than 20%).

Figure 5 also reports the engagement of academics in problem-solving activities with external organisations which are primarily research-based collaborative or contractual

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[12] Starting in 1997 HEFCE made funds available for higher education development projects, including regional development and knowledge exchange activities, student and employer engagement and life-long learning. In 1999 the government set-up the Higher Education Reach-Out to Business and the Community (HEROBC) Fund, the University Challenge Fund (UCF) and the Science Enterprise Challenge (SEC) to encourage knowledge exchange with external organisations. These and related HEFCE initiatives were consolidated into the Higher Education Innovation Fund (HEIF) with the goal of building knowledge exchange capacity and enable its successful delivery. Another long running initiative administered by Innovate UK is the Knowledge Transfer Partnership (KTP) scheme. Under the scheme a graduate works for a firm usually for a two-year period on a specific knowledge-transfer project. The knowledge to be exchanged originates within a qualifying research institution, typically a university. The students are jointly supervised by staff in the company and in the faculty at the university concerned. The firms are typically small and medium sized enterprises (Hughes, 2015). Long established Research Council collaborative doctoral studentships (CASE studentships and CDAs) have also supported people-based links

activities. Such activities are often regarded as central in enabling the translation of research into commercial applications. They also can yield substantial university income as we have discussed earlier. Some of these activities are financed or sponsored by partnering private sector external organisations but as we showed earlier many are supported with public funds, for example EU sponsored research consortia or collaborative Research Council grants. The most used mechanisms relating to problem-solving interaction are joint publications, joint research and the provision of informal advice on a non-commercial basis; each reported by 45% to 48% of respondents. These are followed by consultancy services, participation in research consortia, hosting of external personnel and contract research, with around 30% of respondents involved in each. Prototyping and testing, external secondment and setting up physical facilities are used by far fewer academics.

It is important to note that many of these activities do not occur in isolation but may be used in combination within the same project or in sequence across more than one project. This is a major point to encompass in strategic policy design and we return to it in our multivariate analysis in the next section.

All problem-based activities are considered as important as pathways to impact, with highest importance given to joint research activities. More than 45% of those engaged in joint research consider it as 'very important'. Lowest importance is given to informal advice and consultancy, considered as 'very important' by fewer than 17% of those involved, perhaps due to the lack of a direct research link. It is worth noting that whilst not frequently identified as a very important form of interaction it is a frequently used form of interaction. This suggests that although it represents a frequent way for establishing contacts and may lead to further interactions. These may involve either people-based exchange or other problem-solving interaction. Informal exchange may involve less resource commitment and is not, by itself, regarded as substantively important as other pathways. We explore its interactions with other pathways further in the next section

Figure 5 also reports community-based activities that have not traditionally been a focus of knowledge exchange policy although the UK government has recently shifted its attention towards communities and public engagement (TNS ,2015).[13] Figure 5 shows that there is

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[13] The 2008 consultation paper 'A Vision for Science and Society' called for "high-quality science engagement with the public on all major science issues" (DIUS, 2008: 6). It recognised the public's need for early stage research information and stressed that it wanted to provide "people of any age with access to scientific resources and information" (DIUS, 2008: 8). In 2008, the UK funding bodies and RCUK launched a public engagement pilot scheme that awarded four-year grants 'Beacons for Public Engagement' to six regions in the UK. As part of the initiative the National Co-ordinating Centre for Public Engagement (NCCPE) was established in 2008. The cross-Research Council Connected Communities programme supporting work with community partners and organisation was launched in 2012. HEFCE further launched a Social Enterprise Award (SEA) in 2012 to support universities in developing a structure for social ventures. RCUK sponsored a second round of public engagement initiatives, Public Engagement with Research Catalysts, which started in 2013 supporting six UK universities for a two year period. Their focus was specifically on

substantial interaction between universities and the community through activities such as public lectures and school projects, with about 41% and 29% respectively stating that they engaged in these activities in the past three years; 13% provided public exhibitions. All activities are considered as important as pathways to impact by those using them, though to a lesser extent than problem-solving or people-based activities. On average about 20% of those engaged in community-based activities consider them as 'very important'.

Motivations and Objectives for External Engagement

In order to create the right incentives for academics to engage with external organisations it is important to understand their motivations. The survey therefore asked respondents who had some engagement through people-based, problem-solving and community-based activities with private, public or third sector organisations in the last three years to score a range of motives on a 5-point Likert scale - where 5 is very important and 1 is completely unimportant. Figure 6 shows the mean score for each motivation (blue bars) as well as the share of respondents who consider these important or very important motivations (red triangle). The main motivations to engage with external organisations are concerned with developing the research activities of academics: this includes gaining insights in the area of their research (3.9); keeping up to date with research in external organisations (3.5); and testing the practical application of their research (3.5). Objectives related to teaching are rated slightly lower at around 3. Another important motivation is furthering the institution's outreach mission (3.6), clearly indicating that outreach is perceived as an important activity by many academics. Conversely, motivations that were concerned with financial or commercial gains such as: personal income (2.3) and business opportunities (2.5) were generally considered to be unimportant.

[Figure 6 here]

There are some differences by discipline and by research activity. Academics in engineering and materials science rank all motivations higher than academics in other disciplines – from helping their research to pecuniary benefits. Furthermore, those engaged in applied or user-inspired basic research are more likely to state that they engage with external organisations to benefit their research compared to those primarily engaged in basic research. An analysis by seniority also yields some interesting results: those in research roles rate research and equipment motivations higher compared to the mean, whereas those in lecturer, senior lecturer or reader positions stress teaching and student placement motivations. There are no large differences by gender. In general, the motivations associated with research are similar across the different institutional types. There are, however, differences in the motivations associated with teaching, with academics in the younger universities more likely

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engagement with the wider community and voluntary sector in the regions. The role of cultural and related factors in regional and local growth have also been analysed using the 2009 academic survey results and a related survey of public sector arts and cultural organisations (Hughes et al., 2013, 2014).

to state that they engage with others to improve aspects of their teaching compared to academics in the other institutional groups.

To understand if external engagement brought the desired results, the survey also asked about their impact on research. External engagement could help develop new lines of research, especially research close to the needs of society, and could help academics to better react to teaching requirements. Both help to increase the economic impact and relevance of research and teaching. As shown in Figure 7, 75% of research active respondents who engage with external organisations state that it has given them new insights into their research work; 73% that it led to new contacts in the field; 60% that it led to new research projects; and only 10% consider it to have had very little or no impact. This picture is broadly similar across all disciplines, but the positive impact on research is strongest in engineering and materials science followed by social sciences. Amongst respondents in engineering and materials science, 69% state that it led to new projects. Furthermore, benefits to research are stronger for academics engaged in user-inspired or applied research compared to those engaged in basic research (21% of the latter report little or no impact). Furthermore, the impacts on research are broadly similar across the different institutional types[14].

[Figure 7 here]

Overall, the results on both motivations and impacts suggest that engagement with external organisations strengthens the two core missions of academics – research and teaching. From this perspective both commercialisation and problem solving are not a part of a distinct 'third mission' but are central elements that support and reinforce the two fundamental roles of the university - teaching and research. These motivations and outcomes reflect and are likely to reinforce predispositions to ambidexterity.

Constraints: Barriers to External Engagement

[14] External engagement can also provide benefits for teaching. In general, the propensity to report positive teaching effects is lower than the propensity to report positive research effects. The survey responses show that 53% of respondents that do some teaching and are engaged with external organisations state that it has led to changes in the way they present teaching material. A further 43% report that it led them to make changes to their course programmes. The effect on student employability and skills, however, is only limited. Finally, 28% report that it had no or very little impact on their teaching. There are some differences across discipline: the strongest impacts on teaching can be found for academics in the social sciences, engineering and materials science and arts and humanities. In social science, for instance, 60% changed their material and 51% their course programme. Those in engineering and materials science instead stress student employability more than those in other subject areas (40% of respondents). Teaching impact is also higher amongst those involved in applied research, where only 24% report little or no impact. Impact on teaching is also higher for those in teaching fellow, lecturer or senior lecturer position, i.e. those academic staff that provide most teaching. There are also contrasts between academics in different institutions: those in younger universities consistently rank higher the impacts on teaching compared to academics in other institutions. For example, while only 34% of teaching-active academics at top-decile research institutions report that external engagement changed their teaching programme, 55% of those at post-1992 institutions report such changes. Overall, 37% of teaching-active academics at top-decile research institutions report no teaching effect, compared to only 16% of those at younger institutions. This is consistent with the greater focus on teaching in the younger universities.

The survey results show very high degrees of external engagement amongst academics in the UK but there is, nonetheless, evidence of a range of factors that hinder or limit external interactions which may be central to future strategic policy design.

[Figure 8 here]

Figure 8 reports the importance of various factors that constrained or prevented interactions with external organisations over the last three years. Factors were measured on a 5-point Likert scale - where 5 is highly constraining and 1 is not constraining (values 4 and 5 represent substantial constraints experienced by academics). The most frequently cited constraints for the sample of respondents as a whole are: a lack of time (53%); bureaucratic hurdles within the university (23%); a lack of resources (21%); insufficient rewards (20%); and the difficulty of identifying partners (17%). In contrast, cultural differences and legal barriers regarding IP, reasons regularly mentioned in the literature (Hughes and Kitson**,** 2012) are not considered substantial constraints; although these may be important for the interactions that do involve IP and other related contractual issues, which as we have seen are relatively infrequent activities and vary by discipline. If we just focus on those that have taken out a patent in the last three years, the data shows that 15% of these report that IP issues constrain engagement with external partners compared to just 6% of those who do not report taking out a patent. A comparative analysis by institution type shows that some engagement constraints are higher at newer institutions, perhaps due to higher teaching commitments or fewer resources: in particular, bureaucracy, poor university management skills, lack of resources and a lack of time are more likely to be cited as constraints in younger institutions compared to academics in other institutions. Strategies to intensify further the extent of external engagement clearly face challenges in creating the time to and rewards from doing so relative to overcoming barriers of cultural hostility towards them.

6 The Determinants of Academic involvement in Collaborative Research and other Engagement Activity and its Persistence over time: Multivariate Analysis

In this section we use our panel data to estimate a model of the determinants of engagement over time. We analyse the extent to which persistence is due to academics' individual characteristics, as well as the dynamic effects of past engagement on future engagement and on the interrelationship between collaborative R&D and other exchange activities in the engagement process. The few longitudinal studies available in the literature at the level of the individual academic are restricted to a subset of engagement activities (focussing on patents, industry grants and industry co-authorship), disciplines or institutions.[15] Here we are able to look at the patterns of persistence amongst a wide range of different types of engagement activities over time. In particular we can answer questions about the extent of persistence in external engagement at the level of the individual academic, and what drives

[15] These include Azoulay et al. (2007) using a panel of US life-scientists and using measures of industry-co-authorship and patenting; D'Este et al. (2013) using longitudinal data on industry consultancy and research contracts at universities in Valencia, Spain; Banal-Estanol et al. (2015) using a panel of engineering academics and analysing industry collaboration through UK research council grants.

variations in persistence, exit and entry across individuals, questions that could not be answered to date due to the lack of suitable data (see Perkmann et al., 2013).

The Panel Dataset

The panel dataset was constructed by tracing all the respondents from the first survey who were still in the HEI population sampling frame in 2015 and who responded to the second survey. This involved careful checking, for example of those changing HB I or departmental affiliation. Individuals could fail to appear in the second survey achieved sample because they had retired, or left UK academia, or because they remained in the population sampling frame but did not respond to the second survey. As a result of this checking we were able to form a panel of 4059 individuals who responded to both surveys.[16]

We analyse the probability of engagement in the 2012-15 period in terms of past engagement experience in the period 2005-8 and on a range of the kind of personal, university and subject characteristics which we have presented in the preceding sections. We analyse the impact of past research orientation, past and present Research Council funding, mobility between HEIs and promotion characteristics, seniority, gender, age, discipline (6 broad groups) and institutional type (using the fourfold distinction discussed above).

Probability of Engagement

In the 2015 survey we asked about the 27 pathways to engagement discussed in the previous section. In the 2008/9 survey we asked about academics' involvement in 25 of these engagement forms. For the panel analysis we focus on the 25 engagement activities common to both surveys.[17] A factor analysis (principal component analysis) identified the underlying common rationales of engagement which are categorised into five engagement groups. The first group (*training)* includes relationships encompasses the training of company employees and joint student project-supervision and placements. The second group (*meetings, consulting and advice)* includes informal exchanges with external organisations and advisory agreements that do not require original research. Group three (*collaborative research)* includes commissioned research and original joint research that can involve research consortia or personnel exchange and can result in joint publications with external partners. The fourth group (*commercial activities and services)* includes the commercialization activities discussed above ((patents, licenses and the formation of spin-out companies) combined with prototyping for external organisations and setting up new physical facilities. Finally, group five (*public engagement)* includes engagement through school projects, and public lectures and exhibitions. The full listing of the 25 forms of engagement and the 5 groups produced by the principal component analysis outcomes are shown in Table 3.

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[16] We ran several checks of potential response bias in this sample, including modelling the factors which predisposed answering the second survey conditional on the first. Our conclusion is that any biases are small and we can treat the panel as substantively free from selection bias (Lawson et.al 2016)

[17] Two additional channels of engagement were surveyed but are excluded here. One is the provision of community sports which does not play an important role for academics and does not correlate well with other activities surveyed. We also excluded responses to a question which asked whether researchers ran a consultancy via their research because of its overlaps with a separate questions on the provision of consultancy services.

[Table 3 here]

We estimate an academic's propensity to engage through the five groups of engagement: *training, meetings, consulting and advice, collaborative research, commercial activities and services,* and *public engagement.* Since an academic can, and do, engage through more than one of the groups, in an econometric investigation their standard errors would not be independent. We therefore estimated engagement in these 5 groups of activities simultaneously. We thus estimate a 5-equation multivariate probit model that can be written as:

$$y_m^* = x_m\beta_m + \varepsilon_m, \quad m = 1, \dots, 5 \tag{1}$$

$$y_m = D(y_m^* > 0), \quad m = 1, \dots, 5 \tag{2}$$

$$\epsilon = (\varepsilon_1, \dots \varepsilon_h)' \sim N(0, \Sigma) \tag{3}$$

where *m* represents the different engagement activities.

The variance-covariance matrix ∑ has values of 1 on the diagonal due to normalization, and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements. The log-likelihood function is then given by:

$$lnL = (\beta_1, \dots \beta_h), \Sigma; y|x = \sum_{i=1}^{N} ln\Phi_5\left(\left(q_{i,1,}x_{i,1}\beta_1, \dots, q_{i,h,}x_{i,h}\beta_h\right); \Omega\right) \tag{4}$$

where $\mathrm{q_{i,m}} = 2\mathrm{y_{i,m}} - 1.$

The matrix Ω has values of 1 on the diagonal and $\omega_{j,k} = \omega_{k,j} = q_{i,j}q_{i,k}\rho_{i,k}$ for j ≠k and j,k = (1,..,h) as off-diagonal elements. Φ_h denotes the joint normal distribution of order *5.*

The expression for the log-likelihood function can be evaluated numerically through simulation. We employ the Maximum Simulated Likelihood Method using the user-written command *cmp* in Stata (Roodman 2009).

The multivariate probit not only estimates the propensity of engagement through each of the five modes during the 2012-15 period, but also provides a test of the correlation of the error terms for the five types of engagement. A positive significant correlation suggests that academics make use of more than one engagement modes in the current period. The results of the multivariate probit are reported in Table 4.

[Table 4 here]

The results in Table 4 show that prior engagement in the period 2005-8 is positively and significantly related to engagement in 2012-15 in all five equations. Engaging academics thus display great continuity in their external relationships and this continuity is strongest in *commercial activities and services*.

It is also important to note that prior engagement through one group of engagement activities is most often positively and significantly related to engagement in other groups. This implies that are positive complementarities between past engagement in the different groups of engagement activities and future engagement in these activities. Additionally, the test of correlation of errors shows a high correlation between interactions the different groups modes in the current period. The strongest correlation is between engagement through *meetings, consulting and advice* and *collaborative research*. Academic engagement is thus complex and spans many groups and it should be seen in an holistic manner.

Research orientation and teaching play crucial roles in explaining engagement behaviour. Academics' reported research and teaching characteristics in the 2008/9 survey are used as explanatory factors. The results show that those that those involved in teaching in the 2008/9 survey have a higher probability to engage through *training* interactions, while research active academics are less likely to be engaged in this activity suggesting that there is some complementarity between teaching orientation and engagement mode.

In terms of research orientation, applied researchers exhibit the most personal ambidexterity: they are the most likely to interact through *meetings, consulting and advice* and *collaborative research* compared to those doing no research or motivated by the pursuit of basic research. *Public engagement* is most likely amongst those that do not identify their research as belonging to any of the three research classifications.

We also considered an external indicator of excellence in research activity based on whether an academic was in receipt of Research Council funding. This funding is negatively associated with *training* relationships but positively with all other types of engagement. In particular, past research council funding (during the 2005-08 period) is a better predictor for *commercial activities and services* in 2012-15 than concurrent funding. This may be due to the long-term commitment required for some of these commercial activities to emerge, especially when they involve the establishment of a new company or a longer-term relationship with a specific external organisation. It is striking that past and, even more so, current research council funding is positively linked to *meetings consultancy and advice.* Past involvement in such activities is also positively and significantly linked to *commercial activities and services.* There is thus a strong complementarity between the "softer" modes of engagement through *meetings consultancy and advice* and the "harder" contract-driven modes of *commercial activities and services*. This an important factor to incorporate in the strategic design of support for the latter.

The probability of engagement increases with seniority and is highest for professors. However, research fellows are just as likely to engage through *collaborative research*, *commercial activities and services* and *meetings, consulting and advice* as professors. This is an interesting finding: it could represent a higher degree of social conditioning of early-stage researchers to the intensified external impact agenda. It could also reflect their involvement as non-tenure track post-docs on research council grant funded projects which as we have seen are closely linked to *commercial activities and services* and *collaborative research*.

In terms of gender, women have a lower propensity to engage through *commercial activities and services* than men, but a higher propensity to engage through *meetings, consulting and advice* and *public engagement*. Age does not play a strong role, but younger academics are somewhat more likely to get involved in *public engagement* activities.

With regard to disciplinary fields, we find that those working in engineering and material science or biology, chemistry, veterinary science have a higher probability to engage through *training, collaborative research* and *commercial activities and services*. Furthermore, those working in physics and mathematics are more likely than those in health sciences to engage through *commercial activities and services*. Those in the arts and humanities are the least likely to engage through these modes. They are, however, the most likely to do *public engagement*, (where they are followed by biology, chemistry and veterinary science). Furthermore, the social sciences, health sciences and engineering and material science have a higher propensity to engage through *meetings, consulting and advice* compared to other disciplines. Overall, the results show that there is persistent engagement across all disciplines (STEM and Non-STEM) but the pattern of engagement does vary and just focusing on STEM engagement may ignore the many interactions involving academics in the arts and humanities and the social sciences. Institution type and regional differences are less pronounced and jointly insignificant. This strongly suggest that once account is taken of the main variables that vary by institution (age, gender, seniority and discipline), the institutional form *per se* does not have a strong independe

Conclusions: implications for strategy and policy

The notion that universities should pursue *organisational ambidexterity* may be necessary but not sufficient as universities also need to manage academics who are *personally ambidextrous.* The pursuit of scholarship has historically been undertaken by academics performing the interconnected roles of teacher and researcher. More recently, the role identities of academics have seemingly expanded to include entrepreneur and networker (as well as administrator). It is important to stress, that these roles are not a distinct third arm (or a 'third stream' in the UK parlance) but support the two main activities of research and teaching. The evidence in this paper suggests a number of strategic issues universities should consider to encourage and help their ambidextrous academics to collaborate with industry and to promote innovation.

First, academics do not tend to specialise in one form of engagement with external partners but instead they use multiple mechanisms. This suggests that the range of engagement mechanisms are interconnected and related – for instance, collaborative research may be preceded and stimulated by other forms of engagement such as participating in networks or providing consultancy services. Thus, strategies to promote technology transfer or collaborative research should not be restricted to these forms of engagement alone but should embrace the full spectrum of engagement mechanisms. Universities should promote and support an engagement ecosystem which utilizes the 'public space' convening and meetings role that universities can provide (Cosh, Hughes and Lester, 2006). This means moving beyond the narrow support for research and technology transfer to providing systemic support for informal and meeting and conference based knowledge exchange pathways. It is interesting to note that even in the restricted space of technology transfer in the UK, 43% of our survey respondents were unaware of the existence or the services available from their institution's technology transfer office (TTO).

Second, knowledge exchange involves academics from all disciplines – not just those in science and engineering. This is consistent with other findings that show that industry connects with academics from a wide a range of disciplines (Hughes and Kitson, 2013). It is important, to recognise, however, that the extent and character of engagement varies across disciplines when devising strategies to support both STEM and Non-STEM campus innovation and entrepreneurship. For instance, *training, collaborative research* and *commercial activities and services* are more likely amongst academics in engineering and material science, biology, chemistry, veterinary science compared to academics in other subjects. Non-STEM academics make more use of public engagement routes and meetings consultancy and advice. This may reflect their greater engagement with the public than the private sector but also a greater tendency to form "softer" consultancy businesses. These may prove a more difficult form of engagement to track than the usual technology bacsed commercialization measures but may be an important route into wider business innovation for social science and business school academics.

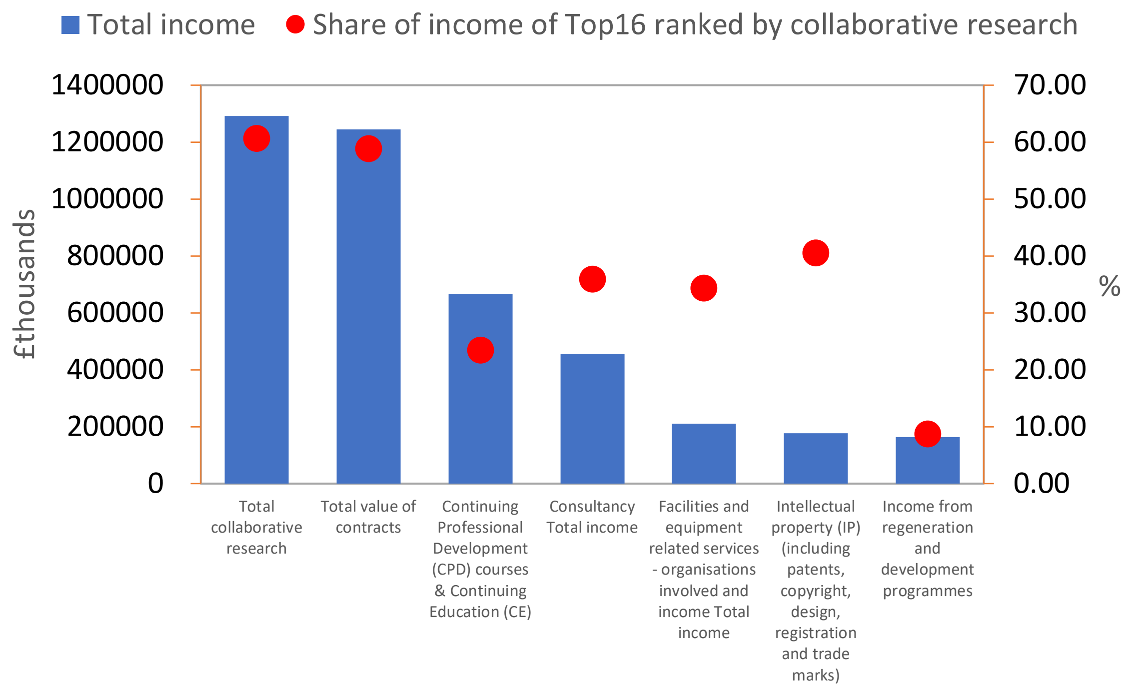
Third, there are differences in engagement activities by institutional type and this will influence the support that universities may seek to provide. But as the multivariate analysis shows, differences in engagement can be largely explained by the different structures of the different institutional types (which in turn, reflects different cultures and objectives or in the terminology of Martin 2012 different speciation). For instance, younger universities are more teaching-focused, have proportionally fewer academics in the STEM subjects and have fewer senior academics. Thus the nature of constraints they face may both be more pressing and different than in other HEIs

Fourth, the practice of engagement is a sustained activity that is often learned through experience. Fundamentally, past engagement drives future engagement. This suggests that training and support for junior academics to learn how to successfully engage with external organisations may help to start academics on a 'pathway to engagement' early on in their careers. Thus, there should be focus on helping to shape academic attitudes and skills in the formative stages of careers to shape future engagement activity. Given the sustained focus on publications in early stage tenure track careers this poses an important strategic management issue. The exposure to exchange may therefore be best made during the early stages of research through research centres or programmes led by senior researchers. This may be consistent with our findings that research fellows and the most senior academics had similar engagement experiences which were greater than those in the early and middle range tenure track positions.

Fifth, there is need for improved metrics. Conventional commercialization metrics are too narrow and a broader range of indicators is required. New measurement techniques are needed – the data currently collected by central university administrators and technology transfer offices often fail to capture the full extent or range of knowledge exchange activities undertaken by academics. Simply, many universities do not know what their academics are doing and the incentives to disclose this wider range may be low. Furthermore, many of the knowledge exchange mechanisms reflect long-term relationships built up from more informal or "softer" arrangements which may not be as easily captured or directly associated with conventional 'hard' economic indicators. The assessment of performance should take into account the variety of objectives and cultures across the different institutional types.

Sixth, many academics in all disciplines do not engage with industry or external organisations – these are often those focused on basic research. These academics are more specialized in their research motivation. They are unlikely to engage and division of labour arguments suggests it may be inefficient to encourage them to change their behavior. Support for engagement is an important part of building an effective engagement ecosystem which promotes collaborative research and promotes innovation. But it is important to respect the important contributions of the 'disconnected' or unidexterous academics who undertake "basic" research which provides the fundamental understanding upon which many advances discoveries and applications by others are built.

Figure 1: Knowledge Exchange Income in UK HEIs 2015/6



Source: Authors own calculations based on HESA 2016

Figure 2: Disciplinary Background (% of respondents)

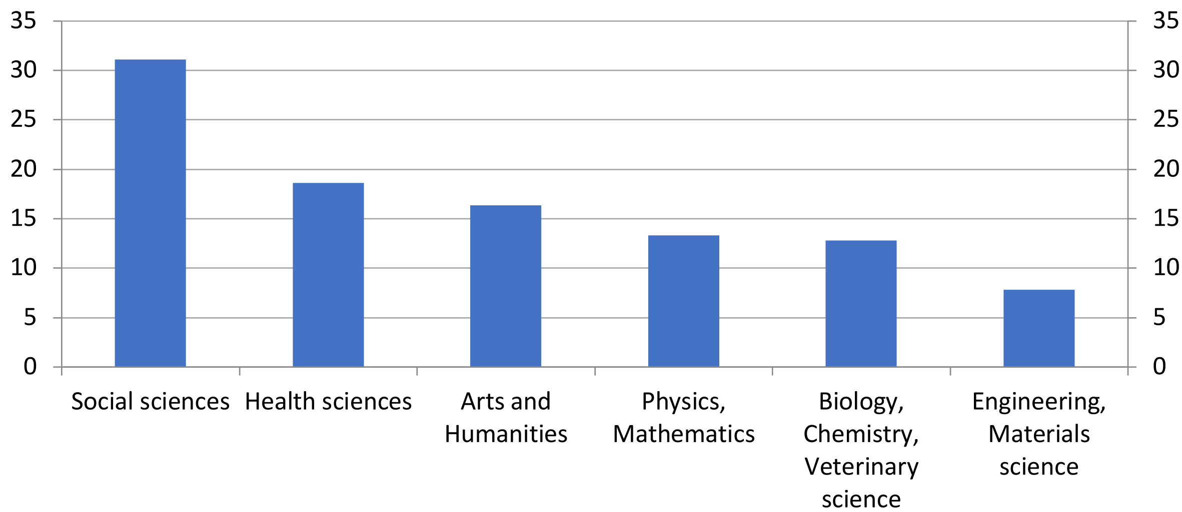
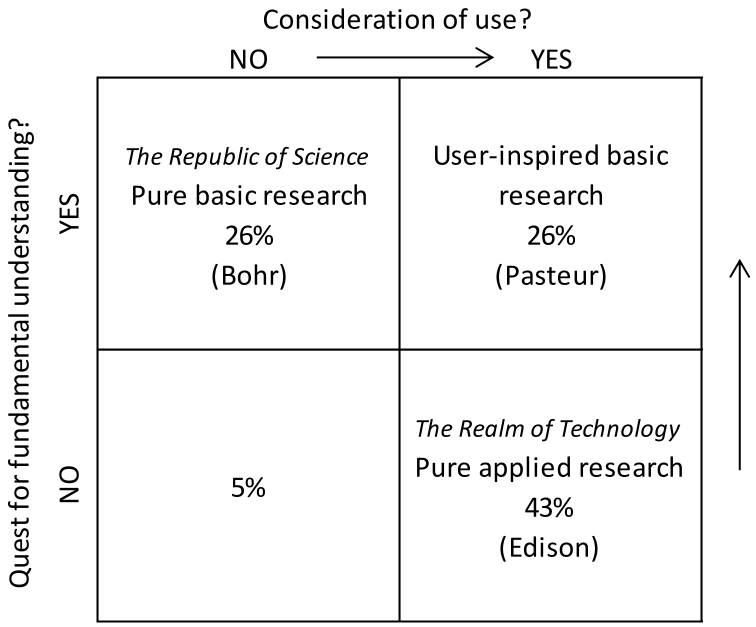


Figure 3: Research Motivation



Source: Adapted from Stokes (1997) and Dasgupta and David (1994)

Table 1: Survey Characteristics data by seniority, gender, discipline, and institution type (% of respondents)

		Professor	Reader, Senior Lecturer	Lecturer	Research Fellow / Associate	Research / Teaching Assistant	Teaching Fellow / Associate	Emeritus / Honorary (retired)	Total (N)	Female
Gender	Male	24	31	19.5	16.3	2.3	1.5	5.5	10554	0
	Female	12	32.8	25.1	20.9	4.2	2.9	2.1	7622	100
Discipline	Health sciences	17.8	31.4	20.6	20.7	3.9	1.9	3.7	3384	58.7
	Biology, Chemistry, Veterinary science	16.6	26.1	16.5	32.4	3.4	0.9	4	2323	36.8
	Physics, Mathematics	20.6	25.8	17.3	27.2	3.9	1.6	3.6	2417	24.1
	Engineering, Materials science	21.9	27.8	20.3	21.8	3.6	1	3.6	1416	16.9
	Social sciences	19	35.8	25.7	10.9	2.2	2.2	4.3	5659	44.6
	Arts and Humanities	19.2	35.5	24.5	9.2	2.6	4	4.8	2978	48.1
Institution Type	Younger universities (est post-1992)	12.5	54.2	22.2	5.8	1.4	1	2.9	5004	46
	Older universities (est pre-1992)	22.1	25.3	25.5	16.6	2.9	2.8	4.7	6086	41
	Specialist institutions	17.7	30.2	23.7	20.1	3.1	1.5	3.8	583	48.4
	Top-decile institutions	21.1	20.6	17.9	29.1	4.5	2.3	4.5	6504	39.1
Total		19.0	31.7	21.8	18.2	3.1	2.1	4.1	18177	41.9

Figure 4: Proportion of research time spent on basic, user-inspired basic and applied research (% of research time)

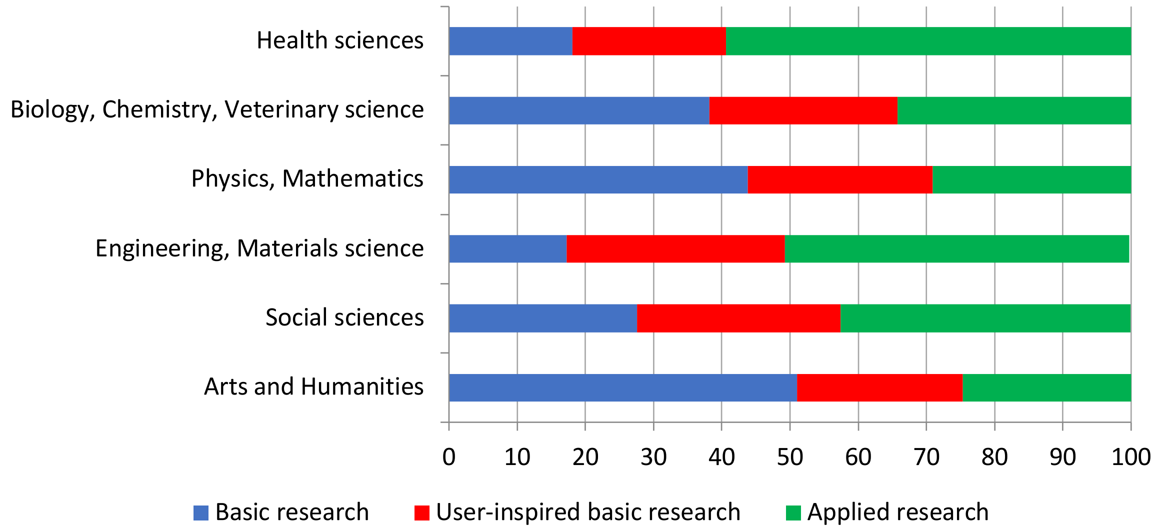


Table 2: Engagement in commercialisation activities in the last three years by gender, position, discipline, research orientation, and institution type (% of respondents)

		Taken out a patent	Licensed research outputs to a company	Formed a spin out company	Total (N)
Gender	Male	8.2	4.5	4	9593
	Female	2.7	1.7	1.3	6944
Position	Professor	10.8	6.4	5.2	3196
	Reader, Senior Lecturer	4.9	3	2.6	5247
	Lecturer	3.3	1.8	1.6	3586
	Research Fellow / Associate	5.9	3	2.3	2995
	Research / Teaching Assistant	3.7	2.8	2.2	493
	Teaching Fellow / Associate	0.6	1.4	2	348
	Emeritus / Honorary (retired)	7.1	2.7	2.7	672
Discipline	Health sciences	4.7	2.7	2.2	3091
	Biology, Chemistry, Veterinary science	14.7	6.1	4.1	2170
	Physics, Mathematics	7.3	5.1	3.7	2184
	Engineering, Materials science	22.2	11.6	7.7	1321
	Social sciences	0.7	0.9	1.8	5079
	Arts and Humanities	0.5	0.9	1.3	2692
Research Orientation	Basic research	3.7	1.5	1.5	4022
	User-inspired basic research	7.3	3.9	3.4	4046
	Applied research	7.4	4.7	3.6	6758
Institution Type	Younger universities (est post-1992)	3.3	2.3	2.6	4566
	Older universities (est pre-1992)	6.1	3.4	3.1	5544
	Specialist institutions	3.9	3.4	0.9	535
	Top-decile research institutions	7.8	4.1	2.9	5892
Total (N)		5.9	3.4	2.8	16537

Figure 5: Non-commercial forms of engagement used in the last three years

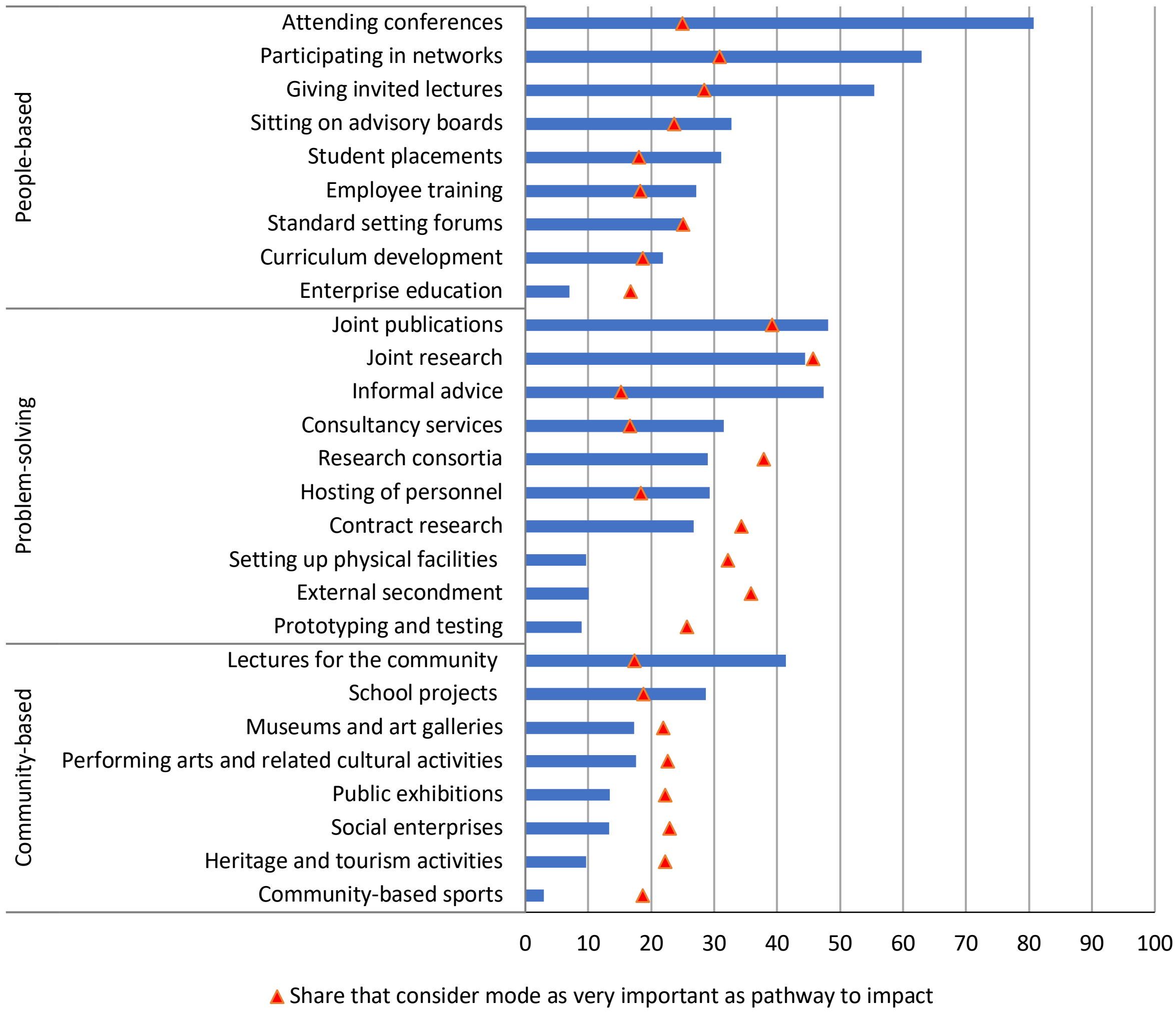


Figure 6: Importance of motivations for activities with external organisations

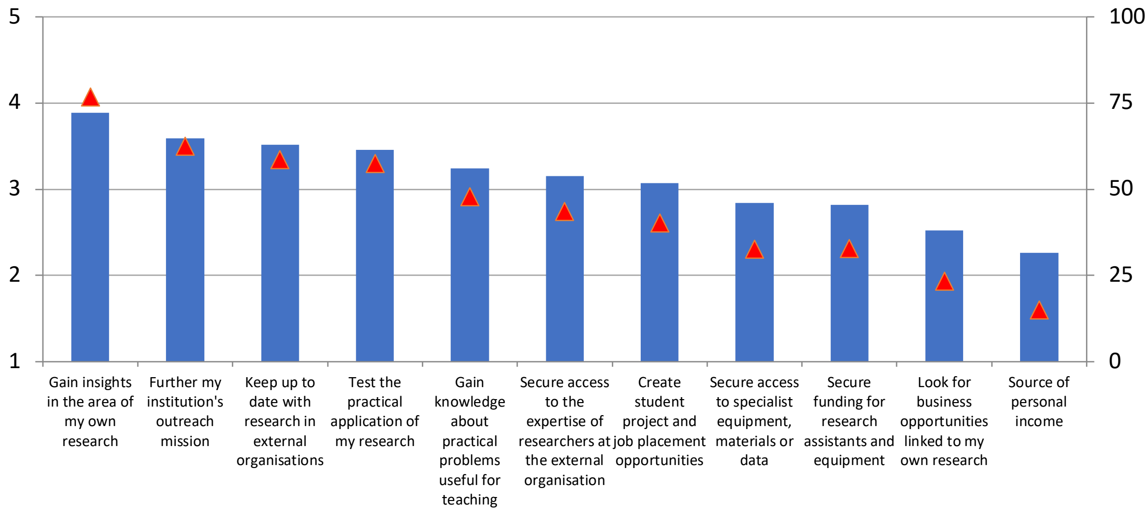


Figure 7: Impact of external activities on research in the last three years

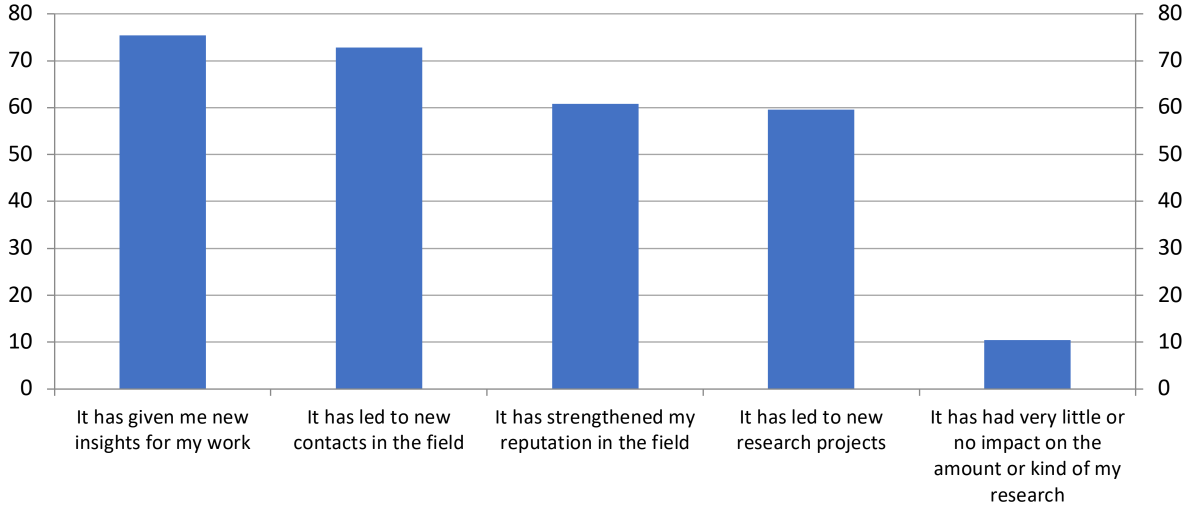


Figure 8: Substantial constraints on interactions with external organisations

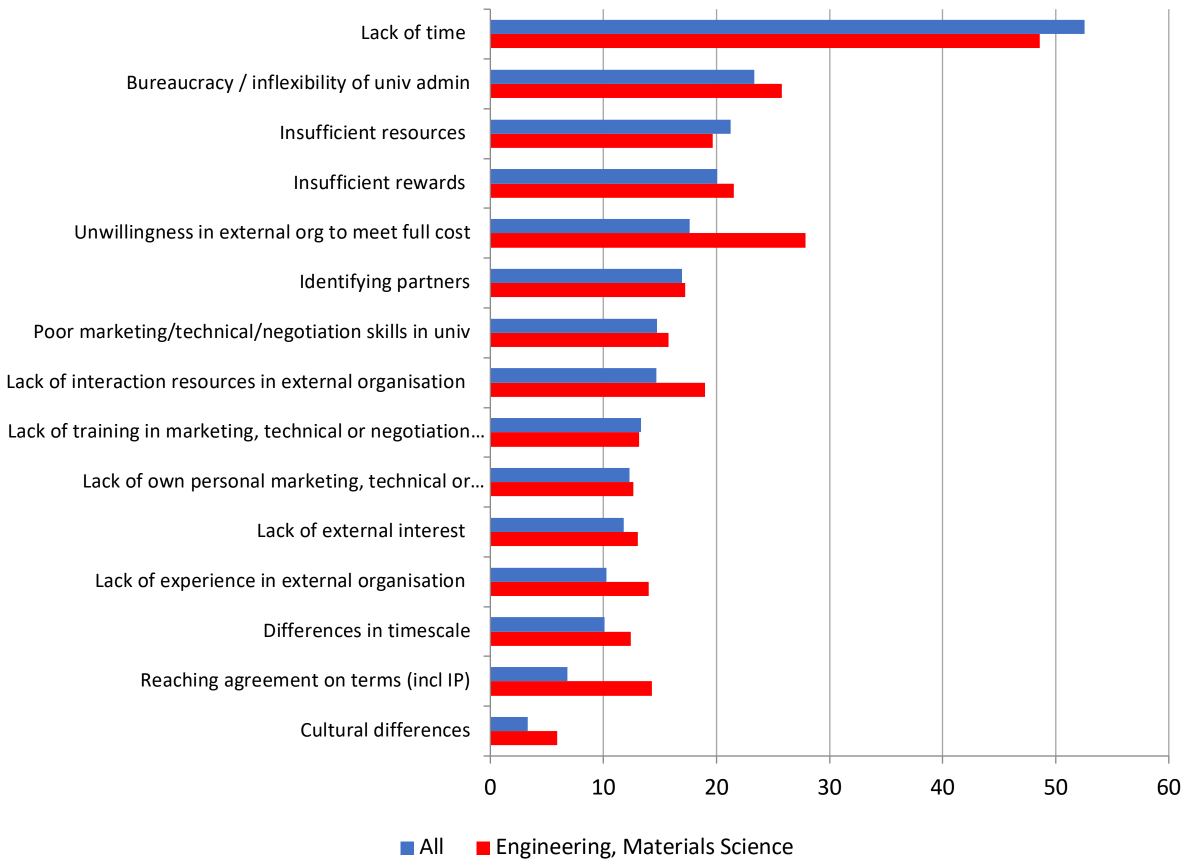


Table 3: Principal component analysis: External engagement activities

Engagement category	Engagement activity in questionnaire	Factor1	Factor2	Factor3	Factor4	Factor5
Training	Employee training	0.134	0.235	**0.570**	0.069	-0.105
	Student placements	0.127	0.145	**0.575**	0.056	0.096
	Curriculum development	0.030	0.185	**0.634**	-0.081	0.070
	Enterprise education	0.051	-0.051	**0.515**	0.100	0.234
Meetings, consulting and advice	Attending conferences	0.275	**0.534**	-0.024	0.012	-0.003
	Standard setting forums	0.138	**0.374**	0.415	-0.036	0.050
	Participating in networks	0.315	**0.540**	0.141	-0.013	0.086
	Sitting on advisory boards	0.150	**0.541**	0.209	0.042	0.160
	Giving invited lectures	0.298	**0.636**	0.038	0.029	0.169
	Consultancy services	0.138	**0.582**	0.236	0.090	0.111
	Informal advice	0.086	**0.486**	0.365	0.217	-0.095
Collaborative research	Joint publications	**0.729**	0.170	0.025	0.060	0.022
	Hosting of personnel	**0.549**	0.100	0.296	0.097	0.169
	External secondment	**0.411**	-0.077	0.246	0.010	0.082
	Joint research	**0.762**	0.183	0.037	0.088	0.018
	Contract research	**0.377**	0.330	0.173	0.206	-0.168
	Research consortia	**0.622**	0.256	0.059	0.126	0.056
Commercial activities and services	Setting up physical facilities	**0.307**	-0.112	0.289	**0.304**	0.278
	Prototyping and testing	0.289	-0.039	0.308	**0.381**	0.098
	Taken out a patent	0.164	0.009	-0.057	**0.734**	0.021
	Licensed research outputs to a company	0.068	0.054	0.028	**0.735**	-0.011
	Formed a spin out company	-0.007	0.090	0.074	**0.691**	0.094
Public engagement	Lectures for the community	0.048	0.356	-0.048	0.023	**0.635**
	Public exhibitions	0.121	-0.004	0.030	0.057	**0.658**
	School projects	-0.020	0.038	0.185	0.044	**0.626**
Rotation variance of loadings		2.708	2.509	2.159	1.963	1.558
Proportion of variance accounted for		10.83	10.03	8.63	7.85	6.23
Cumulative proportion of variance accounted for		10.83	20.87	29.50	37.35	43.58

Note: Loads of the varimax rotation are reported. Highest factor loadings in bold.

Table 4: Multivariate probit model for the determinants of external engagement

	Training$_{12-15}$		Meetings, consulting and advice$_{12-15}$		Collaborative research$_{12-15}$		Commercial activities and services$_{12-15}$		Public engagement$_{12-15}$	
Training$_{05-08}$	0.724***	(0.046)	0.228***	(0.073)	0.258***	(0.052)	0.138**	(0.057)	0.116**	(0.048)
Meetings, consulting and advice$_{05-08}$	0.230**	(0.107)	0.671***	(0.104)	0.384***	(0.104)	0.279*	(0.155)	0.122	(0.100)
Collaborative research$_{05-08}$	0.213***	(0.056)	0.452***	(0.077)	0.632***	(0.056)	0.173**	(0.077)	0.086	(0.057)
Commercial activities and services$_{05-08}$	0.213***	(0.058)	0.180	(0.111)	0.369***	(0.074)	0.957***	(0.058)	0.135**	(0.059)
Public engagement$_{05-08}$	0.183***	(0.045)	0.203***	(0.068)	0.090*	(0.049)	0.226***	(0.054)	0.827***	(0.044)
Research None [base]										
Basic$_{09}$	-0.522***	(0.114)	0.004	(0.142)	0.481***	(0.120)	-0.070	(0.161)	0.517***	(0.119)
User-inspired$_{09}$	-0.275**	(0.113)	0.412***	(0.146)	0.856***	(0.119)	0.144	(0.157)	0.394***	(0.117)
Applied$_{09}$	-0.118	(0.111)	0.587***	(0.147)	1.018***	(0.117)	0.192	(0.155)	0.408***	(0.115)
Other Research$_{09}$	-0.392**	(0.167)	0.409*	(0.223)	0.460***	(0.171)	0.216	(0.229)	0.660***	(0.182)
Teaching active$_{09}$	0.338***	(0.084)	0.133	(0.119)	0.050	(0.091)	-0.057	(0.089)	0.117	(0.080)
Research council funding$_{05-08}$	-0.017	(0.060)	0.194**	(0.093)	0.048	(0.069)	0.130*	(0.068)	-0.092	(0.061)
Research council funding$_{12-15}$	-0.129**	(0.062)	0.273***	(0.099)	0.343***	(0.074)	0.005	(0.069)	0.233***	(0.064)
Mobile since 2009	0.016	(0.061)	-0.004	(0.092)	0.113*	(0.069)	-0.011	(0.073)	0.026	(0.060)
Promoted since 2009	-0.023	(0.050)	0.056	(0.078)	0.136**	(0.056)	0.081	(0.061)	0.103**	(0.051)
Professor$_{15}$ [base]										
Senior Lecturer / Reader$_{15}$	0.000	(0.055)	-0.224**	(0.088)	-0.254***	(0.062)	-0.224***	(0.064)	-0.170***	(0.055)
Lecturer / Teaching Fellow$_{15}$	-0.072	(0.076)	-0.496***	(0.112)	-0.420***	(0.081)	-0.136	(0.091)	-0.191**	(0.075)
Research Fellow / Assistant$_{15}$	-0.263**	(0.112)	-0.223	(0.172)	0.138	(0.123)	0.018	(0.128)	-0.277***	(0.107)
retired$_{15}$	-0.304***	(0.097)	-0.193	(0.135)	-0.099	(0.107)	-0.283**	(0.114)	-0.088	(0.095)
Female	0.017	(0.047)	0.147**	(0.071)	-0.067	(0.051)	-0.252***	(0.058)	0.097**	(0.047)
Age$_{15}$ >=50 [base]										
Age$_{15}$ <40	0.047	(0.083)	0.061	(0.120)	-0.067	(0.087)	0.065	(0.099)	0.203**	(0.084)
Age$_{15}$ 40-49	0.069	(0.052)	0.117	(0.084)	0.002	(0.059)	0.039	(0.063)	0.089*	(0.053)
Social Sciences [base]										
Arts and Humanities	-0.181***	(0.068)	-0.207**	(0.094)	-0.143**	(0.071)	0.074	(0.091)	0.499***	(0.071)
Health Sciences	0.007	(0.063)	-0.171	(0.107)	0.175**	(0.074)	0.272***	(0.080)	-0.090	(0.063)
Biology, Chemistry, Vet Science	0.129*	(0.077)	-0.218*	(0.120)	0.252***	(0.089)	0.753***	(0.085)	0.198**	(0.079)
Physics, Mathematics	0.065	(0.072)	-0.381***	(0.100)	0.044	(0.078)	0.604***	(0.084)	0.049	(0.071)
Engineering, Materials Science	0.365***	(0.099)	-0.084	(0.174)	0.332***	(0.120)	0.877***	(0.096)	-0.064	(0.092)
post-1992 institutions [base]$_{15}$										
top-decile institutions$_{15}$	0.145	(0.160)	0.786*	(0.426)	0.186	(0.206)	0.145	(0.163)	0.136	(0.170)
other old institutions$_{15}$	0.293***	(0.061)	0.077	(0.094)	0.070	(0.067)	0.128*	(0.071)	-0.040	(0.061)
specialist institutions$_{15}$	0.124**	(0.051)	-0.009	(0.077)	0.007	(0.056)	-0.076	(0.061)	-0.112**	(0.052)
Constant	-1.043***	(0.204)	-0.016	(0.269)	-1.149***	(0.218)	-1.930***	(0.269)	-1.177***	(0.202)
Joint sign. of region dummies$_{15}$ $\chi^2(11)$	7.69		17.04		9.40		10.11		8.86	
rho [Training over other]			0.466***	(0.050)	0.348***	(0.033)	0.288***	(0.035)	0.173***	(0.029)
rho [Meetings over other]					0.734***	(0.053)	0.441***	(0.068)	0.310***	(0.045)
rho [Research over other]							0.337***	(0.043)	0.242***	(0.032)
rho [Commercial over other]									0.175***	(0.035)
Number of observations (clusters)	4045 (143)									
LR $\chi 2$	3023.12***									
Log-Likelihood	-8611.957									

Robust, clustered standard errors in parentheses; Clustered at the institution level; Statistically significant at * $p<0.10$, ** $p<0.05$, *** $p<0.01$

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