When does university research get commercialized? Institutional and individual level predictors of commercial outputs from research-council funded projects

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WHEN DOES UNIVERSITY RESEARCH GET COMMERCIALISED? INSTITUTIONAL AND INDIVIDUAL LEVEL PREDICTORS OF COMMERCIAL OUTPUTS FROM RESEARCH-COUNCIL FUNDED PROJECTS

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Abstract:
We examine the tensions that make it difficult for a research-oriented university to achieve commercial outcomes. Building on the organisational ambidexterity literature, we specify the nature of the tensions (between academic and commercially-oriented activities) at both institutional and individual levels of analysis, and how these can be resolved. We test our hypotheses using a novel dataset of 207 Research Council-funded projects, linking objective data on project outcomes with the perceptions of principal investigators. Results show that the tension between academic and commercial demands is more salient at the level of the individual researcher than at the level of institutions.

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WHEN DOES UNIVERSITY RESEARCH GET COMMERCIALISED? INSTITUTIONAL AND INDIVIDUAL LEVEL PREDICTORS OF COMMERCIAL OUTPUTS FROM RESEARCH-COUNCIL FUNDED PROJECTS

The last ten years has seen an increasing emphasis on the generation of commercial outcomes from university-based research. At a policy level, the commercialisation of university research has been viewed as a key driver of national competitiveness, and has been supported by a range of initiatives seeking to promote the links between universities and industry (Henderson et al 1998; Mowery et al 2002). Furthermore, many universities have taken great strides in pushing their commercial agendas and generating more value from their research, by developing Technology Transfer Offices (TTOs), giving researchers more freedom to develop dual career paths, and by challenging the traditional academic mindset. Scholars have suggested that these changes are bringing about an "academic revolution" towards more entrepreneurial universities, where commercial outputs become the norm, rather than an optional side activity (Etzkowitz et al., 2000; Owen-Smith, 2003).

However, such a transition is likely to be both painful and difficult to achieve, and at the moment the evidence of universities developing commercial capabilities is mixed (Gittelman and Kogut, 2002; Krimsky et al., 1991; Owen-Smith, 2003; Slaughter and Leslie, 1997; Stern, 2004). At its heart, the challenge essentially involves taking an organisation that is equipped and accustomed to doing one thing (academic research) and asking it to build a capacity for doing something entirely different (commercial research)

at the same time. And as we know from the significant literature in organisation theory on this subject, such a dual focus is very hard to manage (Duncan, 1976; Gibson and Birkinshaw, 2004; Tushman and O'Reilly, 1997). Tensions arise at the level of the organisation as a whole as it strives to manage two very different sets of activities simultaneously, and also at the level of the individual who has to work out how to balance his or her time between competing demands.

The purpose of this paper is to examine these tensions that make it difficult for a research-oriented university to achieve commercial outcomes. We build on the literature on dual-focused or "ambidextrous" organisations to specify the nature of the tensions (between academic and commercially-oriented activities) at both institutional and individual levels of analysis, and how these tensions can be resolved. From this we then develop hypotheses linking aspects of the institution and the individual researcher to the likelihood of their research projects generating commercial outcomes. Our overarching research question, in other words, is *why do some research projects generate commercial outputs while others do not?*

We test our hypotheses using a new dataset that combines detailed objective data on research projects that have received research council funding combined with the subjective perceptions of the principal investigators on those projects, collected through a questionnaire. To anticipate the findings from the research, we show that the tension between academic and commercial demands is more salient at the level of the individual researcher than at the level of the institution. Universities show evidence that they are

able to manage the tensions between academic and commercial demands, through for example their creation of “dual structures”. At the individual level, on the other hand, the tensions are more acute, so that the people who deliver commercial outcomes tend to be rather different to those who are accustomed to producing academic outcomes. The implications of these findings for research and for policy are discussed.

THEORETICAL BACKGROUND

In recent years, there has been increasing public interest in promoting the commercialisation of university-driven research. This has occurred at both the national policy level across countries, and also among the various institutional players associated with research and innovation (Goldfarb and Henrekson, 2003; Gulbrandsen and Smeby, 2005). For example, there is a growing amount of governmental and institutional funding available for public-private R&D projects, and an increasing number of universities are founding TTOs focused on commercializing scientific discoveries (Clarysse et al., 2005; Goldfarb and Henrekson, 2003). This trend has been driven by a recognition that research conducted in collaboration with industry can be a potent source of innovation (Chiesa and Piccaluga, 2000; Cohen et al., 2002; Lam, 2005; Mansfield, 1991; 1998), and also by changes in governmental policies such as the 1980 Bayh-Dole Act in the United States (Henderson et al., 1998; Mowery et al., 2002).

These trends have been reflected in the academic literature. One body of research has focused on understanding the cognition and behaviours of scientists as potential entrepreneurs (Samson and Gurdon, 1993; Lockett et al., 2003; Owen-Smith and Powell,

2001a,b). For example, Louis et al. (1989) found that academic researchers vary significantly in their entrepreneurial involvement, and Dietz and Bozeman (2005), Lam (2005) and Owen-Smith and Powell (2001a) observed the emergence of increasingly hybrid research careers between academia and industry. A second body of research has focused on the role of university technology transfer activities in the commercialisation of academic research. Studies have examined the trends and drivers of university-born patents and licenses (Henderson et al., 1998; Mowery et al., 2002; Sine et al., 2003; Siegel et al., 2003; Thursby and Thursby, 2002; Chapple et al., 2005), the creation of spin-out companies (DiGregorio and Shane, 2003, Clarysse et al. 2005) and other means of technology transfer by universities (Feldman et al., 2002; Agyres and Liebeskind, 1998, Markman et al., 2005a; Powers and McDougall, 2005).

Taken together, existing research offers useful insights into the factors that lead some academic research projects to produce commercial outcomes: it emphasizes both the importance of the characteristics of individuals (Louis et al., 1989; Owen-Smith and Powell, 2001a), and the resources and capabilities that are brought together (in a university or beyond it) to allow commercial ventures to form (Clarysse et al., 2005; Colyvas et al., 2002; DiGregorio and Shane, 2003; Markman et al., 2005b; Powers and McDougall, 2005). Our research builds on these findings, but it differs in one critical respect from prior studies: we focus at the earliest stage of commercialisation, specifically the decision to pursue a patent, license or spin-out as one of the specific outputs from a research council-funded project. By focusing on this decision point, and by comparing projects that generate commercial outcomes with those that do not, we are

able to provide some important new insights into the early process of commercializing university research.

Tensions between Academic and Commercial Demands

It is widely recognized that commercializing academic research is difficult. At the heart of the problem is the inherent tension that exists between the academic and commercial communities, and these are manifested at both institutional and individual levels.

At the *institutional* level, the key tension is between facilitating the diffusion of new knowledge as a public good and controlling its private ownership and value (Etzkowitz, et al. 2000; Argyres and Liebeskind, 1998). Indeed, as Etzkowitz (1998, p. 824) argues, "[t]he incorporation of 'extension of knowledge' into a compatible relationship with 'capitalization of knowledge' is a profound normative change in science." This change leads to several potential pressure points between academia and the commercial sector (Lockett et al., 2003). First, academia and industry are likely to prioritise different research areas, with industry focused on less risky research with direct commercial applicability while government-funded academic research focused on more uncertain projects with longer time horizons (DiGregorio and Shane, 2003).

Second, academia traditionally encourages knowledge dissemination and full disclosure of methods and results, whereas the commercial sector actively seeks ownership and tight control of intellectual property (Arrow, 1962; Nelson, 1959; Kremer, 1998). This may be slowly changing through the emergence of open innovation platforms (Chesbrough,

2003), but many of the underlying tensions remain. Third, and related to the second point, academic researchers are incentivised to publish their breakthrough ideas as quickly and widely as possible, while commercial interests often seek to delay the publication process and to keep some findings hidden (Blumenthal et al., 1996; Dasgupta and David, 1994; Stern, 2004).

At an *individual* level, the tensions are no less profound. First, there is a strong intrinsic sense amongst scholars that academic and commercial activities represent fundamentally different and potentially contradictory endeavours (Owen-Smith, 2003; Bercovitz and Feldman, 2003). As Dasgupta and David (1994) recognized, communities of scientific peers shape the definition of what constitutes a valuable avenue for research, and this makes it risky for a scholar to deviate from the social norm of conducting 'proper' academic research in order to seek commercial accomplishments (Bercovitz and Feldman, 2003).

Second, commercial activities do not often carry weight in tenure and promotion decisions (Owen-Smith & Powell, 2001a; Markman et al., 2005b). A successful academic career requires significant investment in a specific style of research, paper-writing and network-building, which essentially means little time for pursuing other – commercial – activities (Stephan and Levin, 1992).

Third, many scientists lack the competence to undertake commercial activities as they require different skills and abilities than purely academic ones (Shane, 2002, Lockett et

al., 2003). For example, Clarysse and Moray (2004) found that entrepreneurs who come out of a pure academic environment only gradually learn to adapt to the needs of business. Other studies have shown that academic inventors often bring a strong knowledge of technology but also focus too much on technical issues to the detriment of business considerations (Daniels and Hofer, 1993, Lockett et al., 2003). On the other hand, Zucker et al. (2002) found that 'star' scientists can generate more of *both* academic and commercial results than less successful researchers, so it is by no means impossible for academic research to develop the necessary skills to do well in a commercial environment.

Finally, there is also a dynamic element to the tension between academic and commercial activities. Organisations are products of their administrative heritage (Bartlett and Ghoshal, 1989), and core competences can easily evolve into core "rigidities" (Leonard-Barton, 1992); similarly, individuals are bound by their experiences and socialized into specific work environments (Adkins, 1995; Floyd and Wooldridge, 1999). This path-dependency tends to reinforce existing patterns of behaviour and makes universities, and the individuals that work for them, very difficult to change.

Reconciling the Tensions

How do these tensions get reconciled in practice? While universities have relatively limited experience in managing these tensions, there is a well-established body of literature on "ambidexterity" that provides useful guidance on how organisations create structures and systems for managing conflicting demands in their task environment (e.g.

Brown and Eisenhardt, 1997; Tushman and O'Reilly, 1997; He and Wong, 2004; Duncan, 1976). In essence, this literature argues for the creation of "dual structures" that allow these different and conflicting demands to be managed at the same time: for example new business development is often placed in an autonomous unit (Drucker, 1985; Galbraith, 1982) away from the existing lines of business. While these separate units typically have some lateral processes that link them together, the principal of dual structures allows individuals in each unit to work single-mindedly on one set of demands, while the challenge of reconciling the conflicting demands is left to a small group of senior executives. In the context of academic institutions, such dual structures could include the creation of a TTO, or the assignment of faculty to different groups or tasks (e.g. clinical, teaching, entrepreneurial faculty).

While it is widely accepted that dual structures are an important element in creation of ambidextrous organisations, research has also examined whether it is possible for conflicting demands to be resolved at the level of the individual employee. For example, Adler et al. (1999) identified four approaches individual workers used in a car factory to balance the demands for flexibility and efficiency (switching between different tasks in the course of a day's work, partitioning of activities so they are done in parallel with different teams, meta-routines for systematising the creative process, and job enrichment schemes to make workers more innovative in their everyday tasks); and Gibson and Birkinshaw (2004) focused on how organisations can create a supportive context in which individuals wear "two hats" and make their own informed judgments about how they should allocate their time to meet the conflicting demands for alignment and

adaptability. These two studies suggest it may be possible for organisations to reconcile conflicting demands at the individual level. In the university context, for example, this approach would suggest that individual faculty can switch, perhaps in the course of a single day, between academic and commercial endeavours as long as a supportive context is in place. While not impossible, this would appear to be extremely difficult to do on a consistent basis, a point which Gibson and Birkinshaw (2004) and Adler et al. (1999) both acknowledge.

In sum, the ambidexterity literature offers some useful insights into the structures and systems organisations put in place to manage conflicting demands, and it allows us to develop our own perspective on how universities might best cope with the increased demand for commercial outputs alongside their traditional academic outputs. Specifically, our expectation is that *the tension between academic and commercial outputs is resolved more effectively at the level of the institution (i.e. the university or the research department) than at the level of the individual*. Institutions can put in place dual structures that focus resources and efforts around two distinct sets of outputs, but most individuals lack the motivation and/or the competence to deliver against two different sets of outputs simultaneously[i]. This high-level proposition will now be decomposed into a series of operational hypotheses.

HYPOTHESES

As we explain in detail below, the research was conducted at the project level of analysis, and specifically on research council funded projects conducted by UK Academics. All of

these projects had academic outputs[ii]: the interesting question was why some of them also had commercial outcomes, which we define here as at least one of patenting, licensing or a spin-out company. Hypotheses are developed concerning the different aspects of the institution (the university) and the individual researcher (the principal investigator).

Characteristics of the Research Institution

Universities differ in the degree to which they provide an appropriate infrastructure for the commercialisation of scientific knowledge of their faculty (Markman et al., 2005a,b; DiGregorio and Shane, 2003; Lockett et al., 2003). Our focus here is on two areas where universities can facilitate the creation of commercial outputs: the creation of a TTO, and the removal of constraints around industry collaboration. Both of these can be seen as forms of "dual structure" in that they are providing mechanisms that legitimate commercial behaviour among academics. We also examine the overall research rating of the university as a non-rivalrous resource that can benefit both academic and commercial outputs.

Technology Transfer Office. The role of the TTO is well-established: it helps to bridge the gap between the university and industry by brokering relationships between specific companies and academics and by providing expertise on issues such as technology transfer, creating start-up companies, and licensing (Powers and McDougall, 2005). There is no shortage of research on TTOs, and it consistently paints a positive picture, for example in terms of the relationship between TTO competence and the speed of commercialisation (Markman et al., 2005a), and the success of start-ups that have been

helped by TTOs (DiGregorio and Shane, 2003). We therefore expect that the existence of a TTO in the university where a research project is undertaken will increase the likelihood of a research project having a commercial output.

H1: Research institutions with a specialized technology transfer office (TTO) have a higher likelihood of a commercial output from the research project.

Removal of constraints around industry collaboration. In addition to establishing a TTO, universities can also do a number of more informal things to legitimise the pursuit of commercial outputs and to make collaboration with companies easier. These include establishing liaison officers to build industry relationships, encouraging faculty to pursue industry-sponsored research, and the creation of procedures for streamlining such collaborations (cf. Kenney and Goe, 2004; Owen-Smith and Powell, 2001b). While lacking the formal status of a TTO, these activities collectively signify support for commercially-focused activities that academic faculty can choose to use or not, depending on their own personal preferences. We therefore expect them to have a positive influence on the likelihood of commercial outputs arising from research projects.

H2: The lower the perceived institutional constraints for collaboration with industry, the higher the likelihood of a commercial output from the research project.

Scientific Excellence of the Institution. Finally, we examine the scientific excellence of the institution as a predictor of commercial outputs from a research project. The existing

literature here offers ambiguous findings: Some studies have argued that institutions which are geared towards high-profile academic research may not be able to specialise in commercial activity at the same time (e.g. Slaughter and Lesley, 1997); others have shown a positive relationship between the quality of academic research and the likelihood of interaction with industry (Gittelman and Kogut, 2003; Owen-Smith, 2003; Tornquist and Kallsen, 1994). Our approach here is subtly different to prior studies because our concern is whether the academic excellence of the institution creates any operational tensions around the motivation or ability of academics to develop commercial outputs from their projects. We argue that it does not: scientific excellence (like any form of reputation) is a non-rivalrous resource, which means that its use as an indicator of academic standing does not have to be traded off against its use as an indicator of potential commercial standing[iii]. And in the absence of any such trade-off, we would expect academic research projects from higher-quality academic institutions to generate more commercial outputs.

H3: The higher the scientific excellence of the research institution, the higher the likelihood of a commercial output from the research project.

Characteristics of the Principal Investigator

We have suggested that it is likely to be harder to resolve the inherent tensions between academic and commercial outputs at an individual level than at an institutional level. Here we examine the two arguments that lie behind this proposition. One is based around competence: the skills required to be an excellent academic researcher are not the same as

the skills required to produce commercial outputs, and many academics will struggle to develop both. The other is based around motivation: academic researchers typically enjoy what they do, and are heavily socialised into the norms of their research community, with many of them having no interest in the pursuit of commercial outputs.

Competence to deliver commercial outputs. A particular characteristic of an academic career is the path dependency it induces through long research pipelines, publication review cycles, and relatively hierarchical social structures. Research has shown that researchers accumulate human and social capital over time which affects the formation of scientific careers (Bozeman and Corley, 2004), and has suggested an interesting split between younger, more entrepreneurial 'new-school' faculty and older, more traditional 'old-school' faculty (Owen-Smith and Powell, 2001a). It is therefore very likely that researchers who have come through traditional academically-focused career tracks will often lack the skills and abilities that are needed for pursuing commercial outputs (cf. Shane, 2002, Lockett et al., 2003). This situation may be starting to change as more hybrid forms of academic careers emerge (Dietz and Bozeman, 2005; Lam, 2005; Owen-Smith and Powell, 2001a; Owen-Smith, 2003), but there are still likely to be many faculty who lack the competence to generate commercial outputs, regardless of their motivation.

We operationalise this argument in two ways. First we argue that the greater the researchers' depth of experience in academic research and the more their competencies, relationships, and ways of thinking are geared to the demands of that career track, the lower the likelihood that they will be able to develop the competencies to produce

commercial outputs. This depth of experience is reflected in both the academic position of the principal investigator, as well as the time spent in pursuing academic interests. For example, a professor is likely to have greater experience in academia and to have won more research grants than a more junior academic, but in addition to that we can expect him/her to have a particular area of expertise, and a reputation associated with that expertise, locking him or her more deeply into a chosen career path than someone who is still finding their way in academia. We thus expect that the relatively more junior academics will be more likely to deliver commercial outputs.

H4a: Compared to projects led by professors, projects led by lower-ranking academics will have a higher likelihood of a commercial output.

H4b: The less time the principal investigator has spent in academia, the higher the likelihood of a commercial output from the research project.

H4c: The lower the previous experience the principal investigator has with research grants, the higher the likelihood of a commercial output from the research project.

As a mirror image of the above, experience with industry engagement can also account for a certain path-dependency in academic careers. Researchers with experience in industry interactions may be in a better position to produce commercial outputs (Gulbrandsen and Smeby, 2005). Therefore, we suggest a positive relationship between previous industry experience and commercial outcomes, as follows:

H5: The greater the experience of the principal investigator with industry interaction, the higher the likelihood of a commercial output from the research project.

Motivation to pursue commercial outputs. The other side of the equation in terms of individual-level factors is the level of motivation academics have for commercial activities. Again, it is important to clarify that our focus is on the tension between academic and commercial outputs, and the possibility for individuals to be "ambidextrous". So in other words, we are not so concerned about faculty who are choosing to leave academia to become full-time entrepreneurs; rather, we are concerned with understanding the deliberations of the academic who is seeking to pursue commercial outputs *while also continuing to produce academic outputs*. Such individuals need to satisfy themselves that two conditions have been met: first, they have to have a genuine or intrinsic interest in pursuing commercial outputs; and second, they have to believe that the pursuit of commercial outputs can be achieved without compromising or risking their academic career. In other words, motivation to pursue commercial outputs, in the context of this study, is not just a function of one individual's utility function, it is also linked with the individual perception of compatibility with his/her career. In operational terms, this hypothesis is best expressed as an interaction between two variables as follows:

H6: The higher (a) the principal investigator's belief in the compatibility between industry engagement and an academic career, the stronger the relationship between (b)

the principal investigator's interest in applied research and (c) the likelihood of commercial output from the research project.

DATA AND METHODS

Sample and Data Collection

The data for this project examines 207 academic research projects funded by a major research council in the United Kingdom. It provides a unique data set by combining survey data collected from the principal investigators of these research projects with archival data concerning the inputs and outputs of the projects. As most academic research projects have no commercial outputs, great care had to be taken in the research design. The sampling frame and data collection procedure was designed to provide significant variation in commercial outputs to allow a meaningful statistical analysis, and was achieved by a carefully planned step-wise elimination process.

First, the research projects were all funded by the Engineering and Physical Sciences Research Council (EPSRC), which is UK's premier funding body in the fields of physical sciences and engineering. The EPSRC provided us with access to an archival data set concerning a grant scheme called 'Responsive Mode', which supports high-quality academic research in fields with a technological orientation. One of its explicit aims is to encourage collaboration between academia and industry, and to fill the "middle-ground" between basic academic research and industry-funded contract research. These research projects therefore provide fertile ground for possible commercial outputs, in addition to the academic outputs that are consistently required across all EPSRC projects.

Second, the principal investigators of the research projects, who were recipients of this grant scheme during 1999-2003, were surveyed based on the records obtained from the EPSRC. The range of scientific fields was constrained to ten, leaving aside those fields in which researchers are more likely to draw upon other research councils in their search for funding. The scientific fields included seven engineering disciplines (Chemical Engineering, Civil Engineering, Electrical and Electronic Engineering, Mechanical, Aeronautics and Manufacturing Engineering, Metallurgy and Materials, Computer Science, and General Engineering), Chemistry, Mathematics and Physics. This sampling strategy resulted in a frame list of 4337 principal investigators of EPSRC funded research projects. The survey was conducted between March and May 2004, and a total of 1528 valid questionnaires were returned, representing a response rate of 35.2%.

Third, we then matched this survey data with archival data obtained from the final grant reports handed in over the period of 2003-2005 and retrieved from the EPSRC Management Information System. As the length of a typical grant is more than three years, many of the projects had not finished yet, and were consequently excluded from the analysis. To control for a basic commercial interest, only research projects in which industry had contributed to the project (by providing funding, personnel, equipment or facilities) were deemed eligible[iv]. This rigorous step-wise elimination process resulted in a unique dataset of 207 collaborative university-industry research projects, in which survey data from the principal investigators of EPSRC funded research projects was combined with archival input and output data from the funding body. In addition, we

collected secondary data concerning the research institutions of the principal investigators. Table I provides an overview of the sources of the variables used in the analysis.

Table I about here

Dependent and Independent Variables

Commercial Output

Our dependent variable 'commercial output' was coded as a dichotomous variable. All projects which indicated to have produced a patent, license, spin-out company or a combination thereof, were identified as having 'commercial output' (1). All other projects were assigned as 'no commercial output' (0).

Characteristics of the Research Institution

TTO was measured with a dummy variable to indicate whether the university where the project was located had a Technology Transfer Office. Institutional constraints around industry collaboration was based on the survey data, and assessed the extent to which institutional factors were perceived by the principal investigators to act as a constraint to their involvement in interactions with industry. The items used for this construct were *"Absence of established procedures for collaboration with industry", "Absence or low profile of industrial liaison offices in the university",* and *"Lack of suitable government funding programs for university-industry joint research in specific areas"*, each using a five-point scale ranging from *"not important"* to *"extremely important"*. The validity of the construct was examined using confirmative factor analysis with a good measure of fit

for the factor (p=0.86; CFI=0.966). Scientific Excellence was measured by the ranking of the academic department in which the research project took place, as rated in the UK's *Research Assessment Exercise 2001*.

Characteristics of the Principal Investigator

The prior experience of the principal investigator was measured in three ways. PhD age is the number of years spent in academia after the completion of the PhD, previous grants is the number of previous (although not necessarily collaborative) research grants the individual has gained from the EPSRC, and PI Position is a dummy variable where Full Professor is coded '1' and all other faculty are code '0'. Principal Investigator's interaction with industry was measured as the number of signed agreements or defined contracts to undertake activities such as joint research projects or research commissioned by industry.

In terms of assessing a researcher's motivation to pursue commercial outputs, we used two variables, both derived from the survey. Interest in applied research was measured on a three-item scale, in which respondents had to rate the benefits associated with industry interactions: these were *"Keeping abreast of problems that industry tries to solve"*, *"Becoming part of a professional network"* and *"Feedback from industry about technological viability of research in university"*, and the five-point scale ranged from *"not important"* to *"extremely important"*. The validity of the construct was examined using confirmative factor analysis and indicated an acceptable measure of fit for the factor (p=0.06; CFI=0.962). Second, to measure the perceived compatibility of industry

involvement and an academic career, we used the following scale items: *"Collaboration with industry is detrimental to career progression", "The nature of my research is not linked with industry interests or needs"* and *"Interactions with industry conflict with my teaching and research responsibilities"*. All three items were measured on a five-point scale from *"not at all"* to *"very much"*. For the purpose of our analysis, the items were reverse-coded. Confirmatory factor analysis indicated a good measure of fit for the factor (p=0.46; CFI=0.986).

Control Variables

As prior studies have shown, variation of patenting practices (e.g. Shane, 2002) and a range of different collaboration patterns with business (Meyer-Krahmer and Schmoch, 1998; Chiesa and Piccaluga, 2000) across different industries may influence commercialisation activities. These exogenous factors were added as control variables. First, we controlled for the science field of the project. Second, while all of our selected projects had an industrial partner, some also had collaborations with international academic institutions or institutional partners, such as industry associations. These were added as control variables. It is also conceivable that money provided by the industrial partner may have a different type of effect than more participative forms of collaboration (i.e., provision of personnel, equipment or facilities). Therefore, a dummy variable, industry money, was included to indicate whether research money had been dedicated to the project by the partner(s). Moreover, it may also be possible that bigger research institutions and bigger projects simply have more resources to focus on both academic and commercial outcomes. Hence, we also controlled for the duration of the project[v], the

academic staff time spent on the project (in months), and the size of the academic department. Finally, we also added the academic output of the research project measured in terms of the number of peer-reviewed academic publications[vi].

RESULTS

We begin by presenting some descriptive statistics of our sample. 79 of the 207 projects (38.2%) produced a commercial output: 40 projects formed a spin-out company and a patent or license, 33 had only a patent or license, and 6 had only a spin-out company. The majority of grants (73%) had received money from industry and the average grant size, including the contribution from industry, was around 222,000 GBP. Referring to the characteristics of the principal investigators, two thirds were professors while one third had a lower academic status. For 38% of the grant recipients in our sample, the surveyed project was the first one funded by EPSRC; the remaining researchers had already conducted previous projects with this funding body. Table II presents the bivariate correlations of our independent and control variables.

Table II about here

Given our dichotomous dependent variable, we used binary logistic regression analysis to test our hypotheses. Table III gives an overview of the results. Model 1 presents only the control variables, Model 2 includes all the institutional variables (hypotheses 1-3), and in Model 3 we added the variables pertaining to the principal investigator (hypotheses 4-5).

Model 4 presents the interaction effect (hypothesis 6). Across the four models, we find a significant improvement of pseudo R2 and model fit.

Table III about here

Only one of our control variables, the time academic staff worked on the project, seemed to influence commercial output significantly. It is interesting that we did not find a significant association between academic and commercial output, though this may be at least partly due to the time lag associated with academic publishing. The results pertaining to the six hypotheses were robust across the models. In terms of the characteristics of the research institution, the *existence of a TTO* had a significant impact on commercial output, supporting Hypothesis 1. Although the variable *perceived institutional constraints* had the predicted negative coefficient in our regression, it did not reach significance, so we reject Hypothesis 2. We found a positive and significant effect of the department's *scientific excellence* on commercial output, thereby providing support for Hypothesis 3.

In model 3, in which variables concerning the principal investigator were added, we found strong support for all our hypothesized negative relationships (Hypotheses 4a,b,c) between researcher experience and commercial output. In other words, commercial outputs were more likely in projects run by non-professors with less years experience since their PhD, and with less previous grants from the EPSRC. However, the researcher's level of interaction with industry was not a significant predictor of

commercial output, leading us to reject Hypothesis 5. Finally, in terms of the motivation of the principal investigator, the interaction effect between *interest in applied research* and *perceived compatibility with the researcher's academic career* was significant and positive, thereby supporting Hypothesis 6. It is worth noting that neither of these variables was a significant predictor of commercial output on its own.

DISCUSSION AND CONCLUSIONS

Let us briefly summarise the findings from this study. First, we provided corroborating evidence of the importance of two institution-level factors: the existence of a TTO increases the likelihood that researchers will produce commercial outputs, as does an excellent academic reputation. At the individual level of analysis our results were more surprising. Essentially, we showed that it is the more junior and less experienced faculty who are more likely to produce commercial outcomes. We also showed that faculty who are both motivated to pursue commercial activity *and* who believe it will not harm their academic careers are the ones more likely to generate commercial outputs.

These findings offer important implications for both theory and practice. At a theoretical level, we showed that the concept of ambidexterity (as used in organisation theory) can usefully be applied to universities as they seek to develop the capacity to deliver academic and commercial outputs. Also, consistent with the dominant point of view in the ambidexterity literature, we showed that universities reconcile the tensions between conflicting demands through the creation of dual structures at the level of the university or research department, rather than pushing responsibility for it down to the level of the

individual researcher. This does not mean that individuals have to make a one-time choice to focus on academic *or* commercial work; rather, it says that the responsibility for legitimising commercial outputs alongside academic outputs is held by the university, and individuals are then encouraged to partition their time between the two activities according to a combination of competence and motivational factors (c.f.. Owen-Smith and Powell, 2001). Our research therefore offers no clear support for Gibson and Birkinshaw's (2004) argument that organisations can create ambidexterity through a supportive context. However, it is worth noting that universities typically have a very distinctive form of organisation context that encourages low levels of solidarity and sociability (Goffee and Jones, 2003), so it is perhaps to be expected that Gibson and Birkinshaw's (2004) findings from commercial organisations do not get repeated here.

In terms of practical implications, the research highlights some of the specific things universities can do if they want to increase the volume of commercial outputs from their research projects. Most obviously, they can develop TTOs and other mechanisms for promoting and supporting collaboration with industry. More subtly, they can make it clear that the development of commercial outputs is a legitimate activity, and that it does not compromise a researcher's ability to further his or her academic career. We can also speculate that universities might benefit from providing support for some of their established researchers who are locked into academic research trajectories. This support could come in the form of developing their competence (for example in terms of the ways in which one can generate commercial outputs from a research project) as well as

increasing their motivation (for example by opening their eyes to the possibilities that exist outside academia).

From a policy perspective, the study raises some interesting questions about the sort of researchers and institutions that might be targeted by research councils for support. For example, it is often tempting to view a track record of prior funding as a good sign when considering a new proposal, but our results shows that this negatively affects the likelihood of a commercial output. If the research council is seeking to develop different types of outputs, seniority and strong prior experience are warning signs. It is often said that you cannot teach an old dog new tricks, and the findings from this research are certainly consistent with this aphorism.

Our study does not come without limitations. We chose our sample of research projects very carefully, to ensure that they had both unambiguous academic outputs as well as a significant likelihood of commercial outputs. But of course this creates non-trivial concerns about the generalizability of the findings. We would expect these findings to apply to other contexts where research projects have the potential for both academic and commercial outputs, but a setting where research projects were focused much more on basic research *or* on purely commercial outputs would likely exhibit rather different characteristics. In terms of generalizability to other countries, the UK is among the most advanced countries in terms of public policy towards commercialisation (OECD, 2002) so we would expect to see similar findings in other commercially-responsive countries where government-funded research councils support university research.

Two other limitations are worth noting. First, our broad measure of commercial outputs did not allow us to reveal potential differences between the conditions leading to patenting, licensing and spin-out activities. While these activities clearly need different forms of management as they are developed into profitable ventures, it made sense to group them together as early indicators of commercial outputs from academic research projects. But future research might usefully look at the different conditions that give rise to each different activity. Second, we wanted to develop a high-quality measure of academic outputs to parallel our measure of commercial outputs, but this was impossible with this particular body of data. We included the academic output from the research project at the end of the funding period in our model, but we would have to wait several years to assess the quality and impact of this research (e.g. through citations). This is certainly a direction where this research can be extended in the future.

In conclusion, the purpose of this paper was to investigate the conditions under which academic research projects generated commercial outcomes. Building on the concept of organisational ambidexterity, we showed that the tensions between academic and commercial research outputs can be managed relatively effectively at the level of the university through the creation of dual structures such as TTOs. At the level of the individual researcher, on the other hand, the tensions are more acute, and academics who deliver commercial outcomes tend to be rather different to those who are accustomed to producing academic outcomes.

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Table I: Variables and Data Sources

Controls	**Source**
Science Field	Archival Data
International Collaboration	Archival Data
Institutional Collaboration	Archival Data
Industry Money	Archival Data
Duration	Archival Data
Academic Staff Time	Archival Data
Department Size	Survey
Academic Output	Archival Data
Characteristics of Research Institution	
TTO	Secondary Data
Institutional Constraints	Survey
Scientific Excellence	Secondary Data
Characteristics of Principal Investigator	
Competence	
PI Position	Archival Data
Ph.D. Age	Survey
Previous Grants	Archival Data
Industry Interaction	Survey
Motivation	
Interest in Applied Research	Survey
Compatibility with Academic Career	Survey
Interest x Compatibility	Interaction Term

Table II: Bivariate Correlations (all correlations >146 are sig. p< 0.05)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. International Collaboration	1															
2. Institutional Collaboration	-0.76	1														
3. Industry Money	.023	.188	1													
4.Project Duration	-.075	-.048	.164	1												
5. Academic Staff Time	-.039	-.046	.107	.313	1											
6. Department Size	.054	-.073	-.050	.035	-.021	1										
7. Academic Output	.133	-.023	.155	.028	-.003	.123	1									
8. TTO	-.039	-.001	-.050	.157	-.073	-.065	-.129	1								
9. Institutional Constraints	.111	.006	-.032	.107	-.029	-.064	.000	.023	1							
10. Scientific Excellence	-.053	.028	-.010	.027	.075	.121	-.110	.364	.056	1						
11. Ph.D. age	-.154	.097	.154	.210	.048	-.068	.058	.058	-.174	.064	1					
12. Previous grants	-.081	.106	.214	.068	.037	.045	.111	-.036	-.163	-.051	.400	1				
13. Industry Interaction	-.066	-.042	.076	.083	-.006	-.030	-.046	.064	.056	.025	.121	.061	1			
14. PI Position	-.197	.009	.123	.115	.100	.017	.020	.027	-.146	.059	.544	.369	.152	1		
15. Interest in Applied Research	.082	-.078	-.028	-.029	-.047	.005	-.095	-.016	.108	-.086	-.112	-.089	.069	-.028	1	
16. Compatibility with Acad. Career	-.028	-.005	-.003	-.133	-.020	-.024	-.094	-.092	-.191	-.100	-.013	.039	.149	.109	.227	1
17. Interest x Compatibility	-.083	.081	.031	-.029	-.027	-.055	.022	-.003	-.073	-.026	.043	.003	-.034	.003	-.157	-.255

Table III: Logistic Regression Results

Model	Hypo theses	Model 1		Model 2		Model 3		Model 4	
		B	**S.E.**	**B**	**S.E.**	**B**	**S.E.**	**B**	**S.E.**
(Constant)		-.275	2.282	-1.909	2.489	.241	2.851	.295	2.850
Controls									
Science Fields°		n.s		n.s		n.s.		n.s.	
International Collaboration		-.050	.618	-.190	.631	-.243	.673	-.346	.684
Institutional Collaboration		.367	.399	.400	.408	.142	.433	.222	.442
Industry Money		.022	.356	.075	.363	-.017	.390	-.025	.398
Duration		-.022	.022	-.015	.023	.000	.025	.003	.26
Academic Staff Time		.016**	.007	.017**	.007	.019**	.008	.020**	.008
Department Size		.014	.124	-.060	.130	-.076	.136	-.050	.137
Academic Output		-.015	.050	-.014	.051	.020	.054	.017	.054
Characteristics of Research Institution									
TTO	H1 +			.793*	.453	.922*	.484	.958*	.491
Institutional Constraints	H2 +			-.135	.159	-.226	.176	-.197	.180
Scientific Excellence	H3 +			.344*	.183	.431**	.200	.484**	.204
Characteristics of Principal Investigator									
Competence									
PI Position	H4a -					-1.354***	.453	-1.350***	.455
Ph.D. age	H4b -					-.065***	.023	-.064***	.023
Previous grants	H4c -					-.080**	.035	-.084**	.036
Industry Interaction	H5 +					.003	.020	.002	.020
Motivation									
Interest in Applied Research						.155	.180	.144	.182
Compatibility with Academic Career						.205	.180	.313	.192
Interest x Compatibility	H6 +							.354**	.168
Cox & Snell R Square		.080		.107		.200		.217	
Nagelkerke R Square		.109		.146		.272		.295	
Model Chi Square		17.306		23.518		46.213		50.544	
Significance		.099		.052		.001		.000	
Classification Correct		66.2%		65.2%		72.5%		72.9%	

* p< 0.1; ** p< 0.05; *** p< 0.01

° Regression results controlling for science fields; all coefficients were non significant.

[i] It is important to underline that a significant number of individuals do actually pursue academic *and* commercial activities. However, their efforts in this regard are often facilitated by the institution-level creation of dual structures. For example, at business schools it is common for faculty to "sell" some of their time to an executive development operation or to pursue a contract research project through a Research Centre, both of which are typically formalized activities that the school has decided to make legitimate.

[ii] In their "final grant review", these projects all listed a series of reports and working papers from the research. There had not been enough time elapsed to evaluate whether this research was of a high quality (e.g. through citation counts).

[iii] One caveat to this statement is that universities still have to take great care to decide what activities (academic or commercial) can be done under their banner, because one ill-conceived project can damage the overall reputation of the university. So reputation is non-rivalrous in terms of its use by multiple faculty and projects, but it still needs to be carefully defended.

[iv] This procedure was necessary as a means of ensuring that all projects had some possibility of generating commercial outputs. Without it in place, we would have had less than 10% of all projects with commercial outputs, and we would have been mixing very different types of projects in the same sample.

[v] The total funding of the research project (in GBP) was used as an alternative measure. However, due to a relatively high correlation with the other independent variables capturing the size dimension, it was removed from the final regression analysis. The results remain robust if total funding is added into the equation.

[vi] As hinted earlier, this is not an entirely satisfactory measure as academic publications often take many years to come through. However, we felt it was better to include this weak measure than no measure at all.