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Abstract

We use data from 3000 academic scientists to estimate the effects of other parties' patents on the academics' research. Nearly half of all scientists report that their choice of research projects has been affected by the presence of other parties' patents. We find that transaction costs and the culture of the workplace have the largest influence over whether or not patents affect the direction of research but that scientists' understanding of patent law; their recent experience seeking permission to use patented material; and the source of research funds are also significant.

JEL-Classification: O31, O34

Keywords: public science, innovation, R&D, invention, public research, patent

1. Introduction

As universities around the world have pursued more aggressive commercialization strategies, debate has intensified about the potentially deleterious effects of patenting on scientific community. In particular, concern has been expressed that patents may increase secrecy, hinder informal knowledge transfer and alter the trajectory of scientific inquiry (Eisenberg 1989; Mazzoleni and Nelson 1998; Mowery and Ziedonis 2002; Nelson 2004; Scotchmer 1991). Although there is empirical evidence from surveys of academics in support of these claims (see Blumenthal et al. 1997; Nottenburg et al. 2002; Hansen et al. 2005, Lei et al. 2009, Murray and Stern 2007), others have questioned the contention that patenting has a damaging effect on academic endeavours (Walsh, Arora and Cohen 2003; Walsh, Cho and Cohen 2005; Walsh, Cohen and Cho 2007). Recent research has found that patenting has a positive effect on both the quantity and quality of academic patentees' publications (Azoulay et al. 2009; Fabrizio and DiMinin 2008). Azoulay et al. (2009) conclude that "…the often voiced concern that patenting in academe has a nefarious effect on public research output is misplaced" (p.637). However, their analysis largely ignores one of the major concerns about patents in academe: the effects of patents on third parties. That is, they focus primarily on the direct effect of patenting on a scientist's own subsequent academic publication rate.[1]

In this paper, we focus on the potential negative externalities associated with patenting in countries without a statutory research exemption.[2] In particular, we examine whether patents alter the direction of scientific inquiry in Australia via their decisions about which research projects to undertake. We use data collected from two waves of a survey of Australian scientists administered in 2007 and 2009. In the survey, we ask a specific question about whether the presence of patents in a particular research area shapes the scientist's decision about the direction of their research. Our survey data – which contains 4,513 observations from a mix of patenting and non-patenting scientists in Australian universities and public-sector research institutes ("academic scientists") – suggest that patents have

[1] Azoulay et al. (2009) are aware of this limitation of their analysis. They state that "… the most significant impact of patenting on public research output may well lie in the consequence of the behavior for non-patenting and soon-to-be scientists. We plan to investigate this in the future" (p.671). They also found some evidence that patenting leads to more research on questions with potential commercial interest, which supports the contention that patenting scientists do work on more applied research issues.

[2] All EU member countries, except Austria; Iceland; Japan; South Korea; Mexico; Norway; and Turkey have statutory research exemptions in their patent law. In contrast, the United States, Canada, New Zealand and Australia do not have a statutory exemption. See Dent et al. (2006) for further details.

directly affected the choice of research project (to varying degrees) for approximately 47 per cent of all respondents.

Given this, we then model the determinants of the decision to change research direction, which we hypothesize is influenced by a range of factors. An obvious factor is the scientist's belief about whether researchers are permitted under the law to use patented ideas without the patentees' permission. In common-law countries where there is no statutory research exemption for public-sector scientists – such as Australia – it is unclear whether academic scientists are subject to patent law.[3] We ask a series of questions in the survey regarding scientist's beliefs about the current state of patent law in Australia. The questions are conditioned on: whether the research is conducted within the public or private sectors, and whether the output of the research is to be commercialised or is purely for research purposes. We contend that the scientist is less likely to be affected by the existence of other scientists' patents if they believe that an exemption exists.[4] Over and above this, we develop a number of other hypotheses on the factors which shape scientists' choices over their program of research work, including their recent experience regarding requests to use patented technologies; the culture of the workplace in which the scientist works; and source of research funds the scientist draws on.

As mentioned, nearly half of all scientists report that their choice of research projects has been affected, to some degree, by the presence of other parties' patents. The closest comparator we have for our question comes from biomedical surveys in the US by Walsh, Cho and Cohen (2005) and Walsh, Cohen and Cho (2007). Their respondents indicated that 'too many patents' was rated most highly as a reason for not pursuing projects in 3 per cent of cases, whereas the comparative highest rating for our question was also 3 per cent. It is not possible to quantitatively compare our findings with the Hansen et al. (2005)[5], Nicol and Nielsen (2005)[6] and Lei et al. (2009) due to differences in question format.

[3] The Madey v Duke decision has narrowed the presumption of a research exemption in the United States, but there has been no such recent court judgment in Australia. In the absence of such as judicial determination, the extent of the research exemption in Australia is unclear.

[4] This will also be the case if the scientist believes that there is no exemption, but simply ignores the law, which has shown to be the dominant cultural norm amongst scientists (see Strandburg 2008; Lemley 2008). There is also a third category of individual scientist: those who are unsure whether there is a research exemption or not. As we will see when we present our data, this category accounts for a large proportion of scientists in our survey.

[5] However, note that this study included both private sector and academic scientists.

[6] They reported that "…[a] significant number of respondents we interviewed reported avoiding research in an area because they were aware that another company held a patent to which they required access, and they considered they would have difficulty gaining access to that patent" (p.142), but exact percentages are not given for the academic respondents. Eighteen per cent of companies responded that their company had had "…to change its research program because a patent blocked access to key research tools or materials" (p.140).

It seems likely that patents lead non-patenting scientists into areas of inquiry which are free(er) of patents. Thus, the presence of patents drives a wedge between patenting and non-patenting scientists: the non-patenting scientists are pushed further into the realm of esoteric, abstract science where there are no (or fewer) patents, while the patenting scientists are being pulled further into research with potential commercial value.[7] However, we should point out that we do not observe the direction (or consequences) of any change in research; we simply observe that patents have affected (to varying degrees) the choice of scientific research projects. In this sense, our paper addresses a positive question rather than the normative question "Is this change good for society?"

To answer this normative question requires much more information about the long-term effects of patenting and a much deeper understanding of the way in which science progresses. Unfortunately, we do not have enough evidence to address these issues here. It might be that the changes in the direction of scientific inquiry that we observe here simply represent a more efficient allocation of resources given the capabilities and preferences of the two groups of scientists. Whether this is true remains unknown. What we can say is that the changes we observe contravene one of the touchstones of academia: that scientists should be given "decision rights" over the research projects they work on (see Aghion et al. 2008). Although we know that scientists forego a wage premium to have greater control over their research projects (see Stern 2004), we do not know how this shapes the way in which science progresses. Nevertheless, hundreds of years of scientific progress suggest that the process of "progress" is highly non-linear and uncertain. Imposing constraints on freedom to choose research projects might be a bad idea in such an environment.

2. Background and Hypotheses

Historically, the separation between "science" and "technology" has been quite clear: "science" addressed basic questions about the laws of the universe and made their findings publicly available, while "technology" addressed practical problems and found proprietary solutions to these problems using knowledge often created by science (see Eisenberg and Nelson 2002). As a corollary of this, the boundaries between public and private knowledge were also fairly distinct. Scientists worked in a domain where ideas, research tools and results were freely shared with colleagues via journal publications and academic fora. Technologists

[7] It is probably also true that graduate students working in laboratories which are patent-intensive are more likely to undertake work in patent-intensive areas once they are awarded their PhD. Thus, the changes may be inter-generational.

apply knowledge to create products and processes that are valuable to consumers and in the process earn profits for their company. While useful as a pedagogical device, this binary taxonomy overlooks important areas where science and technology overlap. In fact, an increasing proportion of science is now conducted in the domain – known as Pasteur's Quadrant (Stokes 1997) – where demand-inspired basic research takes place. This has effectively blurred the boundary between science and technology, and has led to a dramatic increase in the extent of patenting in the traditional academic realm.[8] Hand-in-hand with this transformation has been an increased reliance on private sector funding of academic research.

The wisdom of increased patent intensity (and private-sector funding) in academic research has been questioned by many. Mowery and Ziedonis (2002) suggest that privatising public knowledge can have four negative effects: reducing the level of informal knowledge transfer; increasing secrecy; increasing the costs of knowledge and materials transfer; and changing the direction of research. In terms of the effects of patents on scientific productivity, the consensus is that patents and scientific outputs (journal articles) are complements (see Azoulay et al. 2009; Agrawal and Henderson 2002; Fabrizio and DiMinin 2008). Notwithstanding these results, other evidence suggests that we should care about restricting the degree of openness in academic endeavours. Murray et al. (2009), for example, examine the effect of openness on the rate and direction of upstream research. They examine a quasi-natural experiment in the scientific community – the agreements signed by the National Institutes of Health in the U.S. that eased the limitations imposed on academics using genetically engineered mice – and show that openness has a positive effect on the creation of new research programs.

Whether patents can alter the trajectory of scientific progress is partly a function of whether patent law applies to researchers. Historically, academics and public-sector scientists have believed that, as long as they do not commercialise their inventions, they are exempt from patent law. However, the Madey vs Duke case in the United States has resulted in a much narrower research exemption than was previously thought to exist. Although the degree to which a research exemption exists in other countries is unclear, there is widespread concern in jurisdictions without a statutory research exemption, that permission to use

[8] Of course, this transformation was also aided by institutional and legislative changes such as the Bayh-Dole Act in the United States, which promoted university patenting as a way of ensuring that a higher proportion of university output was commercialized.

patented technology is required.[9] The concern is that, in the absence of a research exemption, patenting in the public sector will divert research away from areas which are intrinsically interesting (but heavily patented) into areas which are less interesting (and less intensively patented). In Australia, there is no statutory research exemption and there is widespread concern that the common-law research exemption has been all-but extinguished.[10] [11] In this context, our contention is that the individual scientist's belief regarding the existence of a research exemption determines their behaviour regarding the choice of scientific research project. This can be stated as:

Hypothesis 1: Patents are more likely to alter the direction of scientific inquiry if public-sector scientists believe that there is no research exemption in patent law, ceteris paribus.

Over and above their beliefs about the existence of a research exemption, the direction of scientists' research are likely to be influenced by their recent experience being refused a request to use patented research technologies. Hence we conjecture that:

Hypothesis 2: Patents are more likely to alter the direction of scientific inquiry if public-sector scientists have been denied access to use patent research tools in the recent past, ceteris paribus.

Even if a patent owner grants permission to use the patented technology to another scientist, the direct cost (i.e. the license fee) or the indirect costs (i.e. the transaction costs associated with negotiating the contractual terms of the deal) may be may be substantial enough to make the scientist consider other alternative research questions. This may lead to the creation of what Heller and Eisenberg (1998) referred to as an "anti-commons". This leads us to the development of our next hypothesis:

Hypothesis 3: Patents are more likely to alter the direction of scientific inquiry if public-sector scientists believe that the transaction costs associated with negotiating a deal with patent owners are high, ceteris paribus.

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[9] Even in countries where a statutory research exemption exists, there is increasing overlap between "basic" and "applied" research in areas such as biotechnology which has blurred the lines regarding experimental use and exclusive rights.

[10] We should note, however, that there hasn't been a recent legal dispute in Australia that has tested the existence of a research exemption. Such a dispute is more likely to occur if universities aggressively enforce their own patent rights against firms since this increases the likelihood of retaliation by firms against universities.

[11] Many OECD countries have implemented statutory research exemptions. For an overview of the economic and legal issues relating to research exemptions, see Dent et al. (2006).

Attitudes at the research workplace towards proprietary research, the need for secrecy and value of non-disclosure may also affect how willing scientists are to change their own research program in response to others' patents. We argue that scientists working in environments where traditional Mertonian (Merton 1973) values are very strong will be less likely to change their research inquiry as a result of others' patents – partly because they will ignore them. This culture may also be influenced by the source of funds that the laboratory relies on to finance its experimentation: if there is a greater reliance on external industry funds, where there is probably a stronger emphasis on commercial application of the technology, researchers may be more careful about selecting topics that are heavily patented. This leads to the creation of our two more hypotheses:

Hypothesis 4: Patents are less likely to alter the direction of scientific inquiry if public-sector scientists work in an environment (laboratory or department) which embraces the culture of 'open science'.

Hypothesis 5: Patents are more likely to alter the direction of scientific inquiry if public-sector scientists rely on contract research, commissioned research or industry funds.

3. Survey Data and Descriptive Statistics

Survey data were collected in two waves: February-April 2007 (Wave 1) and February-April 2009 (Wave 2). The survey specifically targeted public-sector researchers in the physical, agricultural and health sciences – which are the most patent-intensive areas of research – across the top eight Australian research universities[12] and major public research institutes in Australia such as the Commonwealth Scientific and Industrial Research Organization.[13] Together, these publicly-funded research organisations account for the overwhelming majority of Australian public-sector research activities. The names and addresses of our target population were collected from the various institutions' websites in January 2007. A

[12] The top 8 universities in Australia are part of a formal collaborative network known as the Group of 8 (or Go8). They are the largest universities in Australia in terms of staff and student, and account for more than two thirds of all the research activity in Australian universities. They include Sydney, Melbourne, Monash, Adelaide, New South Wales, Western Australia, Queensland and the Australian National University.

[13] The Commonwealth Scientific and Industrial Research Organization is Australia's national science agency. It conducts scientific research across a range of areas and employs 6,600 people across Australia. The other research institutes included are Howard Florey, Walter & Eliza Hall Institute; The Austin Hospital; The Garvan Institute, Children's Medical Research Institute ; Australian Wine Research Institute; Australian Centre for International Agricultural Research; and the Australian Nuclear Science and Technology Organisation.

population of 9,597 unique names was collected, and in Wave 1, 2,977 useable surveys were returned (a response rate of 31.0 per cent). Wave 2 used the same population frame as the initial survey and resulted in 1,536 useable responses.[14] Since there are some repeat observations (i.e. scientists who responded to Waves 1 and 2), the sample has 4,513 observations from 3,347 unique scientists.[15] However, after excluding observations with missing variables, we are left with about 3,000 observations in the estimating sample. An examination of responses, presented in the Appendix, indicates that senior, junior and pre-PhD researchers were more likely to respond to the first wave. Junior, pre-PhD and administrators were more likely to respond to the second wave (however the last two groups were small in number). Three-quarters of the population surveyed were either senior or junior researchers with the bulk of the reminder being professorial or head researchers.

Background data on important characteristics such as the scientist's age, gender, department, university, years since completing their PhD, source of research funds, whether they worked in a research-only environment, and research team size were also collected. In addition, both waves of the survey asked questions on the following topics: the understanding of existing patent law; sources of knowledge; patent and licensing behaviour; materials transfer agreements; effects on research and workplace culture.

Previous surveys have used a various questions to quantify the third-party research effects of patents. These have included "the impact of patenting requirements on their ability to publish their research results"[16]; "whether...had to change…research program because a patent blocked access to key research tools or materials"[17]; difficulties gaining access to others' patents[18]; "importance of [reasons] in dissuading your from pursuing that project?"[19]; and "Getting access to proprietary research tools often involves contractual restrictions on publication that cause significant constraints on academic freedom".[20] Additional survey questions have focused more specifically at anti-commons effects and the ease of negotiating with owners of patented technologies.

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[14] We are assuming that the population did not change over this 2-year period. Although this is somewhat unrealistic, the small number of new entrants to (and exits from) the profession over this period is unlikely to change our results substantially.

[15] That is, there are 3,347 scientists who responded to *at least one* wave of the survey. In our empirical model, we account for the fact that some scientists responded to both waves of the survey by clustering over individual scientists.

[16] Nicol and Nielsen (2003, p.127).

[17] Nicol and Nielsen (2003, p.140).

[18] Hansen et al. (2007).

[19] Walsh, Cohen and Cho (2007, p.1188).

[20] Lei et al. (2009, p.38).

We opted for a broader question that did not limit itself either to anti-commons effects, projects that had already commenced or specific types of effects (such as restrictions on publication, excessive royalties). Moreover, we did not ask the respondent to assess whether the effect was positive or negative. Our question asked respondents to rate on a 1(= "no effect") to 7 (= "major effect") Likert scale their position with respect to two contrasting statements: (a) "Other researchers' patents have no effect on which research projects we chose to undertake", and (b) "Other researchers' patents have had a major effect on our choice of research projects".

Table 1, which gives a breakdown of the responses to this question, shows that 53.3 per cent of respondents believe that other researchers' patents had no effect on their choice of research projects. The remainder – 46.7 per cent – indicated that their choice of research projects had been shaped to varying degrees by the existence of other scientists' patents. Although only 2.8 per cent of respondents stated that patents had a major effect on the choice of research project, a total of 24.4 per cent reported a score of between 4 and 7. Engineering, followed by science, indicated the greatest effects. At least at the prima facie level, this suggests that patents are playing a non-negligible role in the direction of scientific progress in Australia. This question forms the dependent variable used in the regression analyses.[21]

Table 1

Effects of Patents on Scientists' Choice of Research Projects, percentage distribution

Faculty	1=no effect	2	3	4	5	6	7=major effect	TOTAL (%)
Medicine	50.6	16.8	7.5	11.3	7.6	3.9	2.3	100
Science	57.5	13.3	6.2	8.9	7.2	4.1	2.9	100
Engineering	44.3	17.9	9.2	11.0	8.9	4.6	4.1	100
Architecture	77.7	5.3	4.3	7.5	3.2	1.1	1.1	100
ALL	53.3	15.2	7.1	10.1	7.5	4.0	2.8	100

Notes: n=4445. Missing =68.
Source: "Freedom to Operate and Scientific Progress" Survey, 2007 and 2009.

Table 2 gives a summary of the variables used in the regression analysis. It reveals that 72.0 per cent of respondents were men, just under a half were research-only staff (as opposed to research and teaching), and the average number of people in each research team was 11.3. Most respondents were in their prime years with the mode being 36-45 years of age but there was fairly uniform spread by years since completing one's PhD. Survey respondents were classified into four broad research fields. This classification was based on the faculty in

[21] This contrasts with the findings of the survey of 414 biomedical scientists in the US by Walsh, Cohen and Cho (2007). Only 3 per cent of respondents indicated that they had abandoned a project because of 'too many patents'.

which the scientist was employed.[22] "Medicine" includes researchers in the various fields of medicine, health sciences, nursing, veterinary science, speech therapy, dentistry and human movement studies. "Science" covers researchers in science, mathematics, information technology, information systems, psychology, agricultural science, microbiology, land and food resources, chemistry, zoology and biology. "Engineering" includes researchers in the various fields of engineering. Finally, "Architecture" includes researchers in the architecture, design and the built environment disciplines. By research field, the breakdown was: Medicine (40.9 per cent), Science (42.1 per cent), Engineering (15.0 per cent) and Architecture (2.1 per cent).

The second column of Table 2 provides the mean rating of the dependent variable (that is, the effects of other people's patents on choice of research project) for each of the categorical explanatory variables used in our analysis. In summary, it shows that research-only scientists, middle-aged scientists (in the 36-45 age bracket) and those from the engineering field of research, were significantly more likely to indicate that their direction of research had been affected by other researchers' patents. There was no significant difference between the 2007 respondents and 2009 respondents (both with the full sample and a matched sample). Gender had no discernible effect.

[22] This may not perfectly correlate with the scientists' exact field of research.

Table 2

Summary of Descriptive Statistics for Explanatory Variables Used in Regression Analysis

Variable	**Percentage of respondents**	**Mean dep. variable (1=patents have no effect, 7=patents have major effect)**
Male	72.0	2.510
Research-only	43.5	2.727***
Size of research team (people)	11.3	
Year 2009	35.5	2.483
RESEARCH FIELD		
Medicine	40.9	2.498
Science	42.1	2.507
Engineering	15.0	2.726***
Architecture	2.1	1.677***
SOURCE OF RESEARCH FUNDS		
Competitive grants (average reported %)	60.1	
Block teaching funds (average reported %)	10.9	
Contract, commissioned funding (average reported %)	22.8	
AGE (YEARS)		
<26	0.3	2.500
26 to 35	18.1	2.509
36 to 45	32.7	2.683***
46 to 55	30.2	2.468
>55	18.8	2.326***
YEARS SINCE COMPLETED PhD		
<6	24.7	2.532
6-10	19.3	2.533
11-15	16.8	2.639*
16-20	12.6	2.535
>20	26.5	2.435
TOTAL	100.0	2.519

Notes: n=3013, **, *** indicate pairwise mean significantly different at 1 and 5% levels respectively. In the case of multiple categories, each category has been compared with all other people not in that category.
Source: “Freedom to Operate and Scientific Progress” Survey, 2007 and 2009.

Finally, Table 3 presents a summary of the responses to the six questions about researchers’ understanding of existing patent laws. Respondents were asked to indicate whether or not they thought a specific statement regarding the need to acquire permission to use patented research technologies was true or false, or whether they were unsure. These questions capture Australian scientists’ beliefs about the existence of a research exemption, which are of obvious importance to our study since scientists will only modify their research direction if they believe that they are required, by law, to obtain permission (or pay a license fee) for the use of patented technologies. The responses reveal that 34 per cent of respondents were unsure about whether or not they needed permission to use patented research tools and techniques if that use is purely for research and 22.5 per cent believed that they did not need permission. Respondents were more likely to believe that researchers needed permission if the researcher was employed in the for-profit sector (even if the use was for research) or if the use had commercial intent (regardless of sector of employment). However, there were high levels of uncertainty about the need for permission if the patent was owned by a public organisation.

Table 3

Scientists' Beliefs about Research Exemptions

Specific Statements Posed in the Questionnaire	True (%)	False (%)	Unsure (%)
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use is *purely for research.*	43.5	22.5	34.0
For-profit sector researchers need permission to use patented research tools and techniques if that use is *purely for research.*	61.4	9.5	29.1
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use has *commercial intent*.	70.1	3.6	26.2
For-profit sector researchers need permission to use patented research tools and techniques if that use has *commercial intent*.	75.1	2.2	22.7
Not-for-profit sector researchers need permission to use patented research tools and techniques if the owner of the patent is a *public organisation*.	41.5	14.0	44.6
For-profit sector researchers need permission to use patented research tools and techniques if the owner of the patent is a *public organisation*.	57.1	5.4	37.5

Notes: n=4514

Source: "Freedom to Operate and Scientific Progress" Survey, 2007 and 2009.

4. Empirical Model

To test our hypotheses, we model the determinants of the decision to change research direction due to the presence of patents in the following way. The decision to change direction – which is represented by the variable we call *ResDir* – is a function of the following factors: the scientist's beliefs about the prevailing law regarding the existence of a research exemption (*LegalUnderstand*); the scientist's recent experience with regard to requests for permission to use a patented research tool (*Experience*); the degree of difficulty associated with negotiating with patent owners vis-à-vis permission to use a patented research tool (*TransactionCosts*); the source of funding the scientist relies on (*Funding*); the culture of their department (*DeptCulture*); and a set of other background factors (*X*) – including age, gender, years since completing PhD, faculty and survey year. We explain the construction of the dependent variable and the set of explanatory variables in the following.

Dependent Variable. To calculate our dependent variable – *ResDir* – we use the survey question with twin anchor statements: 1= "Other researchers" patents have no effect on which research projects we chose to undertake" and 7= "Other researchers' patents have had a major effect on our choice of research projects". The response to this 7-point Likert scale question provides information on the degree to which scientists changed their research direction in response to the presence of patents.

Explanatory Variables. To construct the variable *LegalUnderstand,* we used factor analysis to combine the six statements described in Table 3 about the circumstances in which the respondent believed getting permission to use another's patented technology was necessary. These statements provide a variety of conditions under which a research exemption may or may not exist depending on whether: i) the use of the patented technologies is purely for research; ii) whether the research is being conducted by a for-profit/non-profit organisation; and iii) whether the owner of the patent is a public/private organisation. A high factor score means the respondent thought permission was necessary versus not necessary (or unsure). The variable *Experience* captures whether the scientist has previously encountered situations where a request to use a patented technology was made and whether this request was approved. Specifically, the variable is constructed as the difference between the number of times the respondent had sought permission to use someone else's patented technology over the past year minus the number of times permission was granted. *TransactionCosts* is a factor of Likert scale responses to four statements about difficulties getting information about other researchers' methods, obtaining materials, negotiating with owners and having publication restrictions place upon them. A high figure means these transaction costs are high.

CommercialFocus indicates the mean percentage of research funds that all respondents from the individual respondent's department nominated as coming from "contract, commissioned research, industry funds" (as opposed to research grants and general government funding). This variable captures the strength of the links between a specific department (or research laboratory) and private industry. *DeptCulture* is a factor of six questions relating to pressure from managers to patent, encouragement to publish and present at conferences and encouragement to share information with other scientists. Individual respondent factors are then averaged across the 87 separate academic departments and the two time periods to get a mean departmental figure (there is an average of 25 respondents for each department each year). Higher figures are associated with departments that have stronger links with industry or inculcate a more "open science" culture respectively. The Appendix contains details of exact question asked and the responses.

When attempting to model this relationship, it is important to consider whether the explanatory variables we have identified are, in fact, exogenous to the decision to change research direction. There is at least a prima face case for believing that some of our explanatory variables may be endogenous to the model. Consider the variable *LegalUnderstand*. This variable is probably affected by whether the scientist has previously sought permission to use another scientist's patented technologies (i.e. the variable *Experience*) – but it is hard to see how changing research direction could affect legal understanding. This suggests that the direction of causality must from legal understand to changing research direction. Hence we do not believe *LegalUnderstand* is endogenous. Similarly, as legal understanding is antecedent to seeking permission, the latter is also antecedent to being refused and thus changing research direction. Hence, we also do not believe *Experience* is endogenous although it is reasonable to assume refusals cause a change in research direction. We believe that both the decision to use industry funding by the department or laboratory and its open science ethos are determined by longer-term strategic factors and are therefore unlikely to be caused by individual programmatic changes, hence both *CommercialFocus* and *DeptCulture* are also unlikely to be endogenous (remembering that these two variables are averaged across whole departments and are not individual responses).

However, the respondent's views about difficulties negotiating with other researchers for information, materials and patent permission – which is captured by the variable *TransactionCosts* – may be endogenous since changing research direction is one way to reduce the angst associated with a particular research trajectory. We tested several options to account for this form of endogeneity (reverse causation), and found that the Durbin-Wu-Hausman test did not reject the null hypothesis that *TransactionCosts* were exogenous.[23] Therefore we did not need to used an instrumented approach. We estimated equation (1) in a range of different models: first using OLS, second using a (2-time period) panel data estimation, and third an ordered probit. In each case, we clustered on the individual in order to control for the fact that we have some repeat observations in our dataset (i.e. individual scientists who responded to both waves of our survey).

5. Results

The results of the four models we estimated, which are presented below in Table 5, reveal a high level of robustness. Table 6 presents the marginal effects for each of the significant explanatory variables. Continuous variables were evaluated at one standard deviation above and below the mean, while discrete variables were compared with the base case. Overall, we find strong evidence supporting our hypotheses across the different models. The results reveal that scientists' beliefs about patent law does have a significant effect on whether they

[23] Endogeneity test of endogenous regressors: 0.511; Chi-sq(1) P-val = 0.4745.

have changed direction because of other researchers' patents. Across all four models, the variable *LegalUnderstanding* is positive and statistically significant. Thus, we conclude that there is strong support for Hypothesis 1. This result is consistent with our a priori expectation since it suggests that researchers who believe that a research exemption exists would simply choose to ignore the presence of patents. Such a conclusion resonates with the findings presented in Walsh, Cho and Cohen (2003) and Cohen and Walsh (2007) that the dominant behaviour amongst scientists is "ignore patents". This observation is also backed up by evidence in the U.S. presented in Lei et al. (2009) which shows that some scientists believe that they wouldn't be sued, *even if they infringe*. In this instance, patents would not have any effect on scientists' research trajectory.

There is also some fairly strong evidence supporting Hypothesis 2, which implies that recent refusals to use patented research technologies will subsequently lead scientists to believe that their choice of research projects has been affected. The variable in our model which captures this effect – *Experience* – is positive and statistically significant in all of the estimations. Once again, this result has some intuitive appeal. There was support for Hypothesis 3 that high transaction costs will alter choice of research program. The more researchers' departments relied upon commercial funding, the more likely they were to change their research in response to patents. In addition, research-only scientists were also more likely to report having changed their research direction, possibly because they work in a more applied area. The degree to which the scientist's department embraced the open science ethos was highly significant: scientists were less likely to change the course of their research the more open their departments.

The results on the control variables are also worth noting. Engineering was most likely of all faculties to indicate a change in research direction and architecture the least, *ceteris paribus*. Larger research teams were more likely to have changed direction and young people were more likely to have been affected. However, there was no significant difference by gender, year or time since completing PhD.

Table 5

Regression estimations: Dependent variable is degree to which changed research project because of other researcher's patents

Explanatory variables	OLS	RE	OPROBIT
LegalUnderstand	0.196***	0.169***	0.142***
	(0.0330)	(0.0346)	(0.0241)
Experience	0.249**	0.297***	0.144*
	(0.120)	(0.110)	(0.0757)
TransactionCosts	0.340***	0.316***	0.243***
	(0.0385)	(0.0360)	(0.0275)
CommercialFocus	1.051***	0.913***	0.602***
	(0.317)	(0.302)	(0.192)
DeptCulture	-0.814***	-0.804***	-0.554***
	(0.109)	(0.116)	(0.0693)
Science	0.168**	0.160**	0.0665
	(0.0673)	(0.0772)	(0.0468)
Engineering	0.351***	0.395***	0.220***
	(0.0983)	(0.104)	(0.0586)
Architecture	-0.440	-0.525**	-0.519**
	(0.267)	(0.243)	(0.237)
Male	-0.0243	-0.0432	9.92E-06
	(0.0717)	(0.0772)	(0.0495)
Research only	0.190***	0.164**	0.104***
	(0.0593)	(0.0691)	(0.0394)
Ln(research team size)	0.303***	0.287***	0.200***
	(0.0510)	(0.0443)	(0.0323)
Age	-0.0769**	-0.0643	-0.0702**
	(0.0301)	(0.0489)	(0.0289)
Years completed PhD	0.00702		0.0165
	(0.0643)		(0.0398)
Year 2009		-0.00929	-0.00921
		(0.0318)	(0.0209)
Constant	1.726***	1.787***	
	(0.195)	(0.177)	
Observations	3,013	2,959	2,959
R-squared	0.114		
Fraction of variance due to fixed effect		0.403	

The statistically significant variables noted above are not all of equal impact, The marginal effects reported in Table 6 reveal that *TransactionCosts* and *DeptCulture* had the largest impact (0.5910 and -0.5044 respectively). Faculty was moderately important – compared with Medicine, Architecture was most different (-0.4351). The size of the research team was the only other notable factor with larger teams being more likely to have had their research direction affected (0.4504).

Table 6
Marginal effects: Change to dependent variable due to a given change in the independent variable

Explanatory variables	Change in independent variable…from...compared to	Marginal effect
LegalUnderstand	μ-σ cf. μ+σ	0.3760
Experience	μ-σ cf. μ+σ	0.1271
TransactionCosts	μ-σ cf. μ+σ	0.5910
CommercialFocus	μ-σ cf. μ+σ	0.2419
DeptCulture	μ-σ cf. μ+σ	-0.5044
Science	Science cf. medicine	0.1661
Engineering	Engineering cf. medicine	0.3506
Architecture	Architecture cf. medicine	-0.4351
Research only	yes cf. no	0.1887
Ln(research team size)	μ-σ cf. μ+σ	0.4504
Age	26-35 cf. <26	-0.0763
	36-45 cf. <26	-0.1526
	46-55 cf. <26	-0.2289
	>55 cf. <26	-0.3052

Note: Uses coefficients from Table 5 column 1. Only presents variables that were statistically significant in the OLS estimation.

6. Conclusion

In this paper, we have examined one of the main issues associated with patenting in public research organisations. Specifically, we focus our attention on an empirical evaluation of whether scientists change their choice of research project because of the presence of patents. This issue has largely been ignored in the literature up until now. We utilise data from more almost 4,500 survey responses from research scientists in public research organisations to examine this issue. Our results suggest that scientists are affected by the presence of patents, which is a cause for some concern if we accept that decision rights over research projects should be vested in the individual scientist. Although we cannot quantify the effects of this, or assess whether the effects are positive or negative, we believe that it provides some support for the idea that the government should re-evaluate whether or not to implement a statutory research exemption.

One implication of our results is that scientists may be choosing to move into more "basic" areas of research, since these are more likely to patent-free environments. This suggests that the use of patents in the public-sector may have two countervailing effects. The first is the conventional argument that patenting encourages scientists towards more "applied" research. The second is that, as the amount of patenting in the public-sector increases, scientists may be forced further "upstream" into more basic research realms in order to find patent-free environments in which to conduct their research. There are some valid reasons to argue *a priori* that the impediments to free choice of research project that are imposed by patenting in the public sector research environment may come at some cost. For instance, it is well-known that scientific progress is uncertain and non-linear: even if there is a clear definition of the technological problem at hand, it can sometimes take numerous failed attempts by many different scholars (or research teams) to come up with a solution. In this uncertain environment, one way of pooling the risk is to let many different scientists work on a problem simultaneously. This competition amongst different scientists can generate important benefits – although it is important to note that it can also lead to wasteful duplication of resources. Murray et al. (2009) also demonstrate that one often-neglected cost of protecting IP in academia is that it can reduce the diversity of experimentation.

Data appendix

Table 7

Response rates

Position	Return to sender or not surveyed in 2009 (%)	Replied (%)	No reply (%)	Total (%)	Number surveyed
2007 wave					
Professor/head	31.8	9.5	58.6	100.0	2055
Senior researcher	28.8	16.5	54.7	100.0	2927
Junior researcher	32.3	17.9	49.8	100.0	4232
Pre-PhD	30.8	15.9	53.3	100.0	334
Administration	20.9	7.0	72.1	100.0	49
Total	31.01	15.58	53.4	100.0	9,597
Number	2977	1498	5122	9597	
2009 wave					
Professor/head	18.9	7.2	73.9	100.0	2055
Senior researcher	16.6	9.6	73.8	100.0	2927
Junior researcher	14.3	15.2	70.5	100.0	4232
Pre-PhD	14.7	13.8	71.6	100.0	334
Administration	18.6	16.3	65.1	100.0	49
Total	16.0	11.7	72.3	100.0	9,597
Number	1536	1125	6936	9597	

Table 8

Mean and standard deviation of items used to construct the variables

Item	*Mean score*	*Standard deviation*
ResDir (Dependent variable) – pair of opposing statements (1…7)		
Other researchers' patents have no effect on which research projects we choose to undertake VERSUS Other researchers' patents have had a major effect on our choice of research projects	2.267	1.719
LegalUnderstanding – proportion=true		
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use is purely for research.	0.4352	0.4958
For-profit sector researchers need permission to use patented research tools and techniques if that use is purely for research.	0.6145	0.4868
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use has commercial intent.	0.7014	0.4577
For-profit sector researchers need permission to use patented research tools and techniques if that use has commercial intent.	0.7512	0.4323
Not-for-profit sector researchers need permission to use patented research tools and techniques if the owner of the patent is a public organisation.	0.4148	0.4927
For-profit sector researchers need permission to use patented research tools and techniques if the owner of the patent is a public organisation.	0.5713	0.4950
Experience		
How many times have you sought permission to use someone else's patented technology over the past year? (assumes >5=7)	0.2091	0.6462
How many times was permission granted? (assumes >5=7)	0.1668	0.6064
TransactionCosts *– pair of opposing statements (1…7)*		
We have no difficulty getting information on other researchers' methods VERSUS Getting information on other researchers' methods has been an obstacle for us	3.055	1.816
We have had no difficulty obtaining materials (data or research tools) from other researchers VERSUS Getting materials (data or research tools) from other researchers has been an obstacle for us	3.245	1.772
Negotiating with owners of patented technologies has been easy VERSUS Negotiating with owners of patented technologies has been difficult	4.094	1.705
Patent owners have not placed any restrictions on the timing of our research publications VERSUS Patent owners have placed restrictions on the timing of our research publications	3.444	2.149
Commercial Focus		
Please estimate the breakdown of funds by source for your research department or laboratory? Competitive research grants (ARC, NHMRC etc); Block funds from DEST ; Contract and commissioned research, industry funds	0.2192	0.3091
DeptCulture – pair of opposing statements (1…7)		
We are under pressure from senior management to patent our significant inventions VERSUS There is no pressure from senior management to patent our significant inventions	4.575	2.134
We never disclose our significant inventions before filing a patent application VERSUS We are free to publish or present our inventions without reference to patenting.	4.826	2.146
Scientists working in my field of research are secretive VERSUS Scientists working in my field of research are very open	5.003	1.642
Publishing in a peer-reviewed journal is more important than patenting VERSUS Patenting is more important than publishing in a peer-reviewed journal	2.230	1.767
We are not encouraged to present our findings at conferences VERSUS We are encouraged to present our findings at conferences	6.020	1.537
We are not encouraged to share information on our research program with other scientists VERSUS We willingly share information on our research program with other scientists	5.791	1.477

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