Do Patents Influence Academic Scientists' Choice of Research Projects?*

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Abstract

We use data from 3,224 academic scientists to estimate the effects of third-party patents on scientists' choice of research project. Nearly half of all scientists report that their choice of research projects has been affected by the presence of other researchers' patents, especially those employed in proprietorial and commercial research environments. Across all workplaces however, perceived transaction costs have the largest influence over whether or not patents affect the choice of research project.

Keywords: Public science; Innovation; Invention; Public research; Patents.

JEL Classification: O31, O34

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/or 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 some of these claims (see Blumenthal et al. 1997; Nottenburg, Pardey and Wright 2002; Hansen, Brewster and Asher 2005; Lei, Juneja and Wright 2009; Murray and Stern 2007), others have been more circumspect about the potentially damaging effects of patents on scientific inquiry (Walsh, Arora and Cohen 2003; Walsh, Cho and Cohen 2005; Walsh, Cohen and Cho 2007).[1]

In this paper, we use data from a survey of Australian academic scientists to analyse the degree to which scientists' choice of research projects is shaped by other researchers' patents. Thus, our focus is the externality created by patenting in the scientific realm.[2] Using information about the culture of the scientist's workplace that we collected in the survey, we can identify whether the scientist works in a "communitarian" environment or a "proprietorial" environment. In the "proprietorial" environment, scientists tend to be more secretive and are not encouraged to share their results with the broader scientific community. The "communitarian" environment, by contrast, represents the classic Mertonian scientific environment where scientists are encouraged to present their research at conferences and publish in peer-reviewed journals. We argue that patents are likely to have the weakest effect on the choice of research projects in scientific environments that are communitarian since scientists working in this domain will typically be less likely to work in patentable subject areas, but when they do, may simply ignore (or be ignorant of) patent laws.[3]

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[1] Our concern is with the effects of patents on third parties and thus differs from Azoulay, Ding and Stuart (2009) and Fabrizio and DiMinin (2008) who focus on the direct effect of patenting on a scientist's own subsequent academic publication rate.

[2] Azoulay, Ding and Stuart (2009) argue that such externalities are an important area of study. 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).

[3] There is some evidence suggesting that "ignore patents" is the cultural norm in many scientific domains (see Lemley 2008).

Our data are drawn from two waves – administered in 2007 and 2009 – of a longitudinal survey of academic scientists from Australian universities and other public-sector research organisations in the fields in which patenting is prevalent (including medicine, science and engineering). Of course, not all scientists in these fields work in potentially patentable subject matter areas. And not all scientists who produce potentially patentable material will actually patent their output. In order to take account of these issues, we identified a number of scientific work environments according to their research culture and how focused it was on commercial outcomes. Information on workplace environments was drawn from survey questions about how secretive or open scientists' colleagues are; scientists' recent patenting activity; whether they are employed in a research-only position (or a research-teaching position); and the share of research funds that come from industry. In total, the dataset contains 4,513 observations (and 3,224 individual academic scientists).

In the survey, we asked scientists to rate the degree (on a 1-7 Likert scale) to which other researchers' patents had affected their choice of research projects. In our raw data, almost half of the respondents stated that patents had influenced their choice of research projects (to varying degrees). To be more precise, 46.7 per cent of scientists responded that patents had at least *some* effect of their choice of research project. Although only 2.8 per cent of respondents stated that patents had a "major effect" on the choice of research project, this is still indicative of an issue which requires further analysis and investigation. The closest comparator we have for our question comes from biomedical surveys in the U.S. 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 frequency for the highest rating in our survey was also 3 per cent. It is not possible to compare our findings with the surveys by Hansen, Brewster and Asher (2005)[4], Nicol and Nielsen (2005)[5], Lei, Juneja and Wright (2009) and Davis, Larsen and Lotz (2011) due to differences in question format. Mueller, Cockburn and MacGarvie (2010) however report that 9.1 per cent of innovation-active

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

[5] 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).

private-sector firms modified a project due to difficulties accessing intellectual property rights and a further 3.1 per cent abandoned a project for the same reason.

To investigate the mechanisms by which patents may affect scientists' choice of research projects, we estimate a nested instrumental variable (IV) model for each type of scientific environment and then test for statistically significant differences in the key explanatory variables. The set of explanatory variables we include in the model cover factors such as the scientist's beliefs about whether researchers are permitted under the law to use patented ideas without the patentees' permission (i.e. whether a research exemption exists)[6]; the scientist's recent experience requesting permission from patent owners (including whether any request was granted); and the perceived costs of negotiating with patent owners. Our key findings are that the effects of patents on the choice of research project are far more acute in environments where the mission is to commercialise scientific output and that transaction costs are the most important determinant of the scientist's decision to change research project.

Our over-arching interest in this issue stems from the following: if patents are influencing scientists' choice of research project, it suggests that patents play some role in shaping the trajectory of scientific progress. Although we believe our analysis sheds new light on this complex issue, there are some limitations to the inferences we are able to draw. The main limitation is that we do not know anything about the direction of any change in the research trajectory. Our questionnaire simply asked whether a change had occurred and the degree to which patents influenced this change. While most of the concern about patents in science is that patents deter scientists from working in a specific research space (either because the scientist was fearful of being sued or because the patent signals the scientist's research project is not novel), it is also plausible that patents actually attract scientists to work in a specific (patent-intensive) subject area. In other words, some scientists may be attracted to patent-intensive areas because patent activity signals that it is an area of potential economic value, while other scientists may be deterred by patents. Unfortunately, due to data limitations, we are not able to disentangle these two competing explanations.

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[6] In countries without a statutory research exemption, there exists some ambiguity about the degree to which the common-law research exemption exists. 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. For an overview of the economic and legal issues relating to research exemptions, see Dent et al. (2006).

Even if we were able to observe the direction of the change in research direction, we cannot at this stage evaluate the welfare effects of any change in scientific trajectory since we do not know much about the effects of attracting or repelling scientific inquiry to or from patent-intensive areas. Moreover, the relationship between the "openness" of the scientific environment and the effects of patents on choice of research project may be coloured by the fact that some researchers who believe in open science apparently use patents to protect knowledge from private interests rather than appropriating value for themselves (see Murray 2010).[7] Therefore, to answer the normative question – "Is an observed change in the scientific trajectory good for society?" – requires more information about the long-term effects of patenting and a deeper understanding of the complex non-linear way in which science progresses. It might be that the changes in scientific inquiry that we observe here simply represent a more efficient allocation of resources given the capabilities and preferences of the scientists working in different research environments. However, the changes we observe seem to contravene one of the touchstones of academia – that scientists should be given "decision rights" over the research projects they work on (see Aghion, Dewatripont and Stein 2008).

The next section discusses why the role of patents in science is relevant, particularly in relation to workplace culture and commercial orientation of the scientific environment. In section three, we identify the three distinct types of scientific environments and section four presents details of the survey from which we collected the primary data used in our analysis and some summary statistics. Section five presents the empirical model, while section six discusses the results. Finally, section seven concludes.

2. Patents and Science

Historically, the separation between "science" and "technology" has been quite clear: "science" addressed basic questions about the laws of the universe[8] and made their findings publicly available, while "technology" addressed practical problems and found proprietary solutions to

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[7] We thank an anonymous referee for pointing this out to us. However, it is still not clear why a scientist who advocates openness would go to the trouble of patenting an invention (and putting it in the public domain) rather than just publishing the results in a scientific journal since both are sufficient to prevent someone else patenting the technology.

[8] According to Vannevar Bush: "Basic science is performed without thought of practical ends". Stokes goes on to say that Bush thought the "…creativity of basic science will be lost if it is constrained by premature thought of practical use" (Stokes 1997 p3).

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 were curiosity driven and worked in a domain where ideas, research tools and results were freely shared with colleagues via journal publications and academic fora. In the traditional scientific domain as described by Merton (1973), scientists work in an environment where the ethos of the communitarian scientific paradigm in terms of freely publishing and sharing information with their peers. In this environment, transactions do not occur in a "market" per se and there is a culture of giving that is not conditional on the expectation of reciprocity. Patents play no role in this environment since information is freely shared and scientists do not attempt to commercialise their inventions. Technologists, on the other hand, apply knowledge to create new products and processes that are valuable to consumers and in the process earn profits for their company. Patents clearly play a crucial role here in enhancing appropriability conditions.

While useful as a pedagogical device, this binary taxonomy of "science versus technology" – or the belief that understanding and use are competing goals – 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 the goals of understanding and use are intertwined.[9] 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.[10] Moreover, many inventions in the biotech domain – such as those associated with identification of the human genome – are both important research tools that are inputs into academic scientists' work and diagnostic tools with commercial potential.[11] Hand-in-hand with this transformation has been an increased reliance on private sector funding of academic research, specifically for research which has some potential commercial value.

The wisdom of increased patent intensity (and private-sector funding) in academic research has been questioned by many. For example, Mowery and Ziedonis (2002) suggest that

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[9] The classic example given by Stokes is the rise of microbiology in the nineteenth century (Stokes 1997, p12). Pasteur sought an understanding of the process of disease and also discovered a way to stop the spoilage of beer, wine and milk; cholera in people; and rabies in animals. This led to the germ theory of disease with which we are so familiar.

[10] 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.

[11] However, as Huang and Murray (2009) point out, scientists have been producing potentially valuable scientific and commercial work for a long time. For instance, Pasteur, Shockley, and Cohen-Boyer produced patents and scientific publications on their research output.

privatising public knowledge can have four negative third-party effects: reducing the level of informal knowledge transfer; increasing secrecy; increasing the costs of knowledge and materials transfer; and changing the direction of research. The small amount of evidence on these third-party effects suggests that there are valid reasons to be concerned.[12] Murray et al. (2009), for example, examine the effect of openness on the rate and direction of upstream research. They use a quasi-natural experiment in the scientific community – the agreements signed by the National Institutes of Health in the U.S. which eased patent-related limitations imposed on academics – and show that openness had a positive effect on the creation of new research programs. Not only did "openness" increase the level of follow-on research, it substantially increased the rate of exploration of diverse research projects. This led Murray et al. (2009) to conclude that one of the often-overlooked costs of introducing patents into the scientific realm is the negative impact it has on the diversity of experimentation.

Unless we can quantify the magnitude of this stimulus to diverse research trajectories as well as the impact of patents on the economic value of chosen research projects and the amount of downstream investment, theoretical predictions of the welfare effects of the welfare system will be ambiguous. That is, excluding these considerations from analysis will reduce theoretical models of the welfare implications of openness and secrecy to a standard public good situation.[13]

To understand how patents may affect scientists' choice of research projects, consider the following stylised decision path. Let us start from the point where a scientist has chosen a research topic. At some point in time after this choice has been made, they may or may not decide to search through the universe of prior art contained in a patent database and find an existing patent in the relevant research space. This search may have been undertaken, for instance, because the scientist works in a domain where some of their output has potential commercial value and freedom-to-operate issues are important considerations for commercialization of inventions. Or it may simply be standard operating procedure for their workplace. Following this, there is a set of sequential decisions that they will go through in order to determine whether to ignore the patent, modify the project in order to work around the patent, or abandon the project altogether.

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[12] There is better documentation of first-person effects – that is the effect of patents on the scientist's own productivity. The consensus is that patents and scientific outputs (journal articles) are complements (see Azoulay, Ding and Stuart 2009; Agrawal and Henderson 2002; Fabrizio and DiMinin 2008; Huang and Murray 2010).

[13] As in Mukherjee and Stern (2009).

If a blocking patent has been found to exist, then the scientist has to decide whether a license is required under the prevailing law.[14] If the scientist believes that the research potentially infringes the patent, then their assessment of the probability of legal action by the patent owner is relevant to the decision-making process. Only those scientists who believe they are infringing, are likely to be caught and sued by the patent owner, will take action to avoid infringing. While detection may be difficult at the research stage, it is much easier once a product goes to market. Scientists working towards commercialising their research will therefore be more sensitive to the possibility of legal action by the patent owners. We expect that scientists who believe that a blocking patent exists – but do not believe there is a credible threat of being sued – will simply proceed with unlicensed use of the patented invention. There is evidence that this is a common practice amongst the scientific community (see Eisenberg 2011; Lemley 2008).

Having reached the point where the scientist has: observed a blocking patent; believes that they require a license to use the patented technology; and accepts that the threat of enforcement by the patent owner is credible; he or she then has to decide whether they should apply for a license or change their research project. This decision about whether to apply for a license (and ultimately to accept the terms of the licence) will be determined by the magnitude of the expected transaction costs relative to the expected value of the research project (Eisenberg 2011). Note that in analysing this decision, we assume that it is possible for the scientist to replicate the patented technology *without* the patent owners' permission.[15] That is, any license is required purely for legal reasons and we assume away exchange of scarce materials.[16]

Transaction costs – by which we mean time spent by scientists and lawyers negotiating the terms of a license, any royalties that are incurred, and any restrictions placed on the scientist by the patent owner – should be lower if either the workplace has a dedicated IP management unit, or, the bargaining process with the patent owner is done cooperatively.[17] Scientists working in more commercial workplaces are likely to be able to pay higher license fees (give the expectation of future revenue) and they may also experience lower transaction costs (if they have

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[14] If there is no statutory research exemption, beliefs about the extent of a common law research exemption are relevant.

[15] That is, the scientist is not seeking transfer of materials as in the case of the Oncomouse.

[16] If the cost of replication is high, there are two reasons why a third party patent may change the choice of research projects – to comply with the law and to gain cheaper access to materials. Although access to materials is important, our focus here is purely on the legal aspects.

[17] The bilateral trading arrangements between academic scientists and industry over patent licenses are complex. We do not provide a comprehensive overview of these issues here.

a dedicated IP management unit). Conversely, scientists working in a non-commercial environment are typically budget-constrained (or at least budgets are fixed ex ante), and therefore have less scope to cover transaction costs. However, they are also more likely to receive generous treatment from the patent owner, not in the least because their research may actually enhance the value of the patented technology. That is, they may receive a free license. It has been noted that patent owners often offer a portfolio of different licensing options according to the mission of the scientist's workplace – see Williams (2010). However, patent owners may also impose other unfavourable conditions on academic scientists such as forcing them to delay publication of any scientific results (see Czarnitzki, Grimpe and Toole 2011).

In sum, patents will only affect the scientist's choice of research project under the following conditions: the scientist decides to search through databases of patents in-force; the search results in finding a blocking patent; the scientist believes that there is no research exemption and or the scientist wants to provide a freedom-to-operate warranty for downstream users; the scientist believes the patent owner will sue them for unlicensed use (if detected); and the scientist is unable to negotiate a licence on agreeable terms. Our contention is that commercially-orientated scientists will be much more likely than their non-commercial counterparts to satisfy the first five of these six conditions. The only point at which non-commercial scientists are likely to be more affected is at the point of negotiating licenses. However, to get to this stage, they will have had to have (logically) passed through the other points. Therefore, we expect only a comparatively small number of non-commercial scientists will reach this critical point.

3. Defining the Scientific Environment

So far, we have presented a stylised theoretical framework suggesting that two distinct workplace characteristics bear upon our research question. The first relates to the workplace culture – whether it embodies the ethos of open and unfettered exchange between colleagues. The second is the mission of the organisation – whether it aims to conduct research for the sake of knowing or research for the sake of a specific outcome. There is a substantial body of literature supporting the theory that "…professional imprinting and [the] localized social context…" affect individual behaviour (i.e. Bercovitz and Feldman 2008) and the role of lead scientists in determining the behavior of their team (i.e. Göktepe-Hultén 2008).

Although it is often assumed that these two characteristics are perfectly correlated – that is, workplaces either conform to an open-science and non-commercial type or a proprietary-science and commercial type – there is increasing evidence that a third type, which involves an open-science but commercial mission, exists.[18] This third type may conform to the hybrid organization of Murray (2010) in which scientists adapt legal tools (patents, contracts *inter alia*) to suit their ends – i.e. the need for funding or the desire for the efficient production of research tools – while still rooting themselves in the traditional academic milieu. Or, the type of hybrid organisation described by Jain, George and Maltarich (2009) wherein the scientist adopts a "…focal academic self and a secondary commercial persona." Haeussler and Colyvas (2011) suggest that how this conflict is handled depends on the seniority of the academic: more senior and established (male) academics are able to blend science and commerce more successfully than others. For some time, Etzkowitz (1998) and Etzkowitz et al. (2000) have argued that a stance of moderate involvement by traditional teaching academics in commercial engagement – the so-called "entrepreneurial university" – has been becoming more commonplace.

Within the scientific landscape, Etzkowitz (1998), Huang and Murray (2009) and Gans, Murray and Stern (2010) have suggested a number of possible typologies. The latter define the scientific organisation types in terms of four disclosure strategies: "secrecy" where scientists don't disclose research findings at all, "commercial science" where scientists patent their research, "open science" where scientists publish their research, and "paper-patent pairs" where scientists both publish and patent their research. The view that a hybrid type exists, appears to contrast with Bercovitz and Feldman (2008) who have argued that when a conflict occurs between two sets of norms, one set becomes subservient.

Our hypothesis is that scientists from different environments react to beliefs about the law and expectation of transaction costs in different ways. As such it makes sense to model the behaviour of scientists from communitarian and proprietorial environments separately. Picking up from the suggestions from Murray and others, we also experimented with whether a third alternative embodying an open ethos but commercial mission was present in the data and behaved in a different way. As we show later in the paper, we identify three distinct types of

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[18] *A priori*, it is logically inconsistent to have a proprietary-science but non-commercial environment.

scientific environment: “open-&-non-commercial”, “open-&-commercial” and “proprietorial-&-commercial”. Although our terminology is different, our scientific environments are broadly consistent to those outlined by Etzkowitz (1998), Huang and Murray (2009) and Gans, Murray and Stern (2010).

4. Survey Data and Descriptive Statistics

To test our hypotheses, survey data were collected by return post in two waves: February-April 2007 (Wave 1) and February-April 2009 (Wave 2).[19] The population frame for the survey was public-sector scientists in the physical, agricultural and health sciences – which are the most patent-intensive areas of research – across the top eight Australian research universities[20] and senior scientific staff from the major public research institutes in Australia such as the Commonwealth Scientific and Industrial Research Organization (CSIRO).[21] Together, these publicly-funded research organisations account for the overwhelming majority of Australian public-sector research activities.

The names and addresses of our sample of scientists were collected from the various institutions’ websites in January 2007.[22] In total, 9,597 unique names were collected and initial contact with the survey recipients was made via postal delivery. In an attempt to improve response rates, survey recipients who did not respond to the initial mail-out were sent two subsequent mail-outs in Wave 1 and one subsequent mail-out in Wave 2. In Wave 1, a total of 2,977 useable surveys were returned (a response rate of 31.0 per cent). Using the same population frame as Wave 1,[23] we received 1,536 useable responses (a response rate of 16.0 per

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[19] The purpose of conducting two waves of the survey was to gain an understanding of inter-temporal changes in the effects of patents on scientific inquiry. We expect to conduct the survey in subsequent years.

[20] 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 students, 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. Names and addresses were collected from the organisations web site in early 2007.

[21] CSIRO is Australia’s national science agency. 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.

[22] Only individuals listed on the organisation’s web page were included in our sampling frame. While this provided comprehensive coverage of universities, the coverage of the medical research institutes and CSIRO was incomplete.

[23] A small number of scientists (n=68) who did not want to participate in the project asked to be removed from the database. They were not sent a survey in Wave 2.

cent) in Wave 2.[24] Since there are some repeat observations (i.e. scientists who responded to Waves 1 and 2), we have 4,513 observations from 3,224 unique scientists.[25] After excluding observations with missing variables, we are left with 4,315 observations in the estimating sample.

Survey recipients were classified into four broad research fields. This classification was based on the faculty in which the scientist was employed.[26] "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 of respondents was: Medicine (40.2 per cent), Science (43.5 per cent), Engineering (14.1 per cent) and Architecture (2.1 per cent).

An examination of responses is presented in Table A1 in the Appendix. About half of the population of scientists surveyed were either senior or professorial researchers or heads of department. In both Waves, responses were evenly spread across junior and senior researchers. We test for non-response bias by comparing the mean response of those who return the first mail-out with those who responded to subsequent mail-outs in each Wave. Respondents who replied to the second (or third) mail-out are used to construct a control group of non-respondents to the first mail-out. The logic is that people who feel strongly about an issue are more likely to respond early and without prompting, such that any systematic difference in the two mail-out samples would indicate an underlying (and unobserved) overall response bias (Pearl and Fairley 1985).

Table A2 provides the means of the survey items by mail-out. It indicates that there was no statistical difference for 14 of the 16 questionnaire items. The only statistically different items were those measuring the difficulty of obtaining materials from other researchers (those who had

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[24] We assumed 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.

[25] That is, there are 3,224 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.

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

"no difficulty" were more likely to respond to the first mail-out) and whether the department valued publishing in a peer-reviewed journals over patenting (those which "favored peer-reviewed journals" were more likely to respond to the first mail-out). Both of these biases are the opposite of what we would expect if more concerned scientists responded without prompting. Importantly for the research question addressed in this paper, there was no tendency for scientists who felt their research direction had been affected by others' patents to respond differentially to the mail-outs. Finally, we note that there was no statistical difference between the mean of the responses according to survey year. The mean of the dependent variable was 2.282 and 2.238 in 2007 and 2009 respectively (in the paired t-test, t= 0.8095). In sum, there is no evidence of response bias.

Previous surveys have used a variety of questions to quantify the effects of others' patents on scientific inquiry. These have included "the impact of patenting requirements on their ability to publish their research results"[27]; "whether...had to change…research program because a patent blocked access to key research tools or materials"[28]; difficulties gaining access to others' patents[29]; "importance of [reasons] in dissuading your from pursuing that project?"[30]; and "Getting access to proprietary research tools often involves contractual restrictions on publication that cause significant constraints on academic freedom".[31] In contrast, our survey 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".[32] Thus, our question does not address anti-commons effects, nor does it consider specific types of effects (such as restrictions on publication). Moreover, we did not ask the respondent to assess the direction of the change (toward or away from patent-intensive areas). The closest question to ours is by Davis, Larsen and Lotz (2011) who ask Danish scientists to "… evaluate what [they] believe has been the

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

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

[29] Hansen, Brewster and Asher (2007).

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

[31] Lei, Juneja and Wright (2009, p.38).

[32] We do not know if the changes the respondent report actually occurred in the sense that there is no audit or third party verification of what is going on. We simply have to rely on the belief that the scientist's response to the question was unbiased.

impact of patenting activities by academic researchers in your field [on] freedom to choose research subjects…”.

Table 2, 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 researchers’ 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. Responses to this question are used to construct the dependent variable used in the regression analyses. The distribution of responses across research field indicates that academics in engineering – followed by science – were more likely to report a “major effect” than academics in other disciplines. At least at the prima facie level, this suggests that patents are playing a non-negligible role in the choice of scientific research projects in Australia.

Table 2: Effects of Patents on Scientists’ Choice of Research Projects, by Research Field, Percentage Distribution

<table>
<tr><th>Faculty</th><th>1=no effect</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7=major effect</th><th>TOTAL (%)</th></tr>
<tr><td>Medicine</td><td>50.6</td><td>16.8</td><td>7.5</td><td>11.3</td><td>7.6</td><td>3.9</td><td>2.3</td><td>100</td></tr>
<tr><td>Science</td><td>57.5</td><td>13.3</td><td>6.2</td><td>8.9</td><td>7.2</td><td>4.1</td><td>2.9</td><td>100</td></tr>
<tr><td>Engineering</td><td>44.3</td><td>17.9</td><td>9.2</td><td>11.0</td><td>8.9</td><td>4.6</td><td>4.1</td><td>100</td></tr>
<tr><td>Architecture</td><td>77.7</td><td>5.3</td><td>4.3</td><td>7.5</td><td>3.2</td><td>1.1</td><td>1.1</td><td>100</td></tr>
<tr><td>ALL</td><td>53.3</td><td>15.2</td><td>7.1</td><td>10.1</td><td>7.5</td><td>4.0</td><td>2.8</td><td>100</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="4">24.4</td><td></td></tr>
</table>

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

Background data on 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 the survey. Table 3 gives a summary of the characteristics of respondents. It reveals that 69.9 per cent of respondents were men, 41.6 per cent were research-only staff (as opposed to research and teaching), and the average number of people in each research team was 8.3. Most respondents were in their prime years with the mode being 36-45 years of age but there was a fairly uniform spread by years since completing one’s PhD. The second column of Table 3 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, scientists in the 36-45 age bracket and those from science, engineering and architecture 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.

Table 3: Respondent Characteristics, Summary

Variable	**Percentage of respondents**	**Mean dep. variable (1=patents have no effect, 7=patents have major effect)**
MALE	69.6	2.279
RESEARCH-ONLY	41.6	2.470***
SIZE OF RESEARCH TEAM (PEOPLE)	8.3	
YEAR 2009	34.0	2.238
RESEARCH FIELD		
Medicine	40.2	2.295
Science	43.5	2.190***
Engineering	14.1	2.525***
Architecture	2.1	1.606***
SOURCE OF RESEARCH FUNDS		
Competitive grants (average reported %)	56.8	
Block teaching funds (average reported %)	10.8	
Contract, commissioned funding (average reported %)	21.9	
AGE (YEARS)		
<26	0.3	2.429
26 to 35	17.4	2.276
36 to 45	32.4	2.417***
46 to 55	29.4	2.268
>55	20.5	2.030***
YEARS SINCE COMPLETED PhD		
<6	24.0	2.320
6-10	19.5	2.298
11-15	17.1	2.381*
16-20	17.1	2.305
>20	27.2	2.127***
TOTAL	100	2.267

Notes: n=4513, *, *** indicate pairwise means significantly different at 10 and 1% 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.

5. Empirical Model

5.1 Identifying Scientific Environments

To test our hypotheses, we first sought to identify different scientific environments in the sample of responding scientists. We used 10 survey items to form three partition clusters according to the workplace culture and organisational mission of the research unit (laboratory or department) in which the scientist works. The complete set of questions used to form the clusters is reported in Table 5.[33] As mentioned, we define three types of scientific environment as “open-&-non-commercial”, “open-&-commercial” and “proprietorial-&-commercial”. The clustering was done at the individual scientist level, not the organisational unit. Thus, it is possible that scientists working in the same laboratory or department are in different clusters. Approximately one third of scientists are in each cluster.

We measured workplace culture (communitarian or proprietorial) as the degree to which scientists agreed with the following statements (measured on a 1-7 Likert scale): scientists in my field of research are very open; publishing in a peer-reviewed journal is more important than patenting; we are encouraged to publish our research findings at conferences; we willingly share information on our research program with other scientists. Note that these statements are actually a mix of questions relating to the scientist’s specific workplace plus some questions about other scientists in their field of research. However, they all relate to important dimensions of the ethos in which the scientist is immersed.

The organizational mission (commercial or non-commercial) of the workplace was measured by the degree to which scientists agreed with the following statements (measured on a 1-7 Likert scale): we are under pressure from senior management to patent our significant inventions; and we never disclose our research findings before publishing a patent. In addition, the construction of the organizational mission includes information on: the percentage of research funds in the scientist’s lab/department that originates from “contract, commissioned research, and industry funds” (as opposed to research grants and general government funding); whether the scientist was employed in a research-only capacity (as opposed to a position

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[33] Cluster analysis is the art of finding natural groupings in the data that minimize distances within the group but maximize the distances between groups. Our clustering was based on medians using Euclidean distance measures. If the scientist responded to both waves, the mean response to each item was used so that each scientist will be in the same cluster in both waves.

involving research and teaching); how many patents they currently hold; and whether they had applied for a patent in the past 12 months. Source of funding is one clear indicator of commercial orientation since private industry will typically only fund research that has some potential commercial value.[34]

Table 4: Employing Units, by Cluster

	Cluster 1 (n= 1,321)	Cluster 2 (n= 1,757)	Cluster 3 (n= 1,155)		
Type of employing unit	**Open-&-non-commercial**	**Open-&-commercial**	**Proprietorial-&-commercial**	**Total**	
	%	**%**	**%**	**%**	**Number**
University - department	34.5	43.2	22.4	100	3,247
University - institute or centre	33.3	41.7	25.0	100	156
Independent research institute	11.0	32.0	57.0	100	363
Hospital-based institute	23.6	37.3	39.2	100	467
Total	31.2	41.5	27.3	100	4,233

Table 4 presents a breakdown of clusters by the type of research unit. The different types of "employing unit" – which were manually coded using the name and address of the unit – were defined as the traditional teaching and research university department; non-teaching research units located within universities; stand alone research units and hospital-based research units. In our sample of respondents, we found that university departmental scientists are most likely to be in the open-&-non-commercial and least likely to be in the proprietorial-&-commercial clusters. By contrast, independent research institute staff are least likely to be in the open-&-non-commercial and most likely to be in the proprietorial-&-commercial clusters. Scientists from hospital-based institutes leaned more towards independent research institutes than the traditional academic department and university based institutes leaned more towards the latter.

Table 5 presents a summary of the characteristics used to construct each cluster. It illustrated some key differences across the three scientific environments. In particular, it shows that scientists in the open-&-non-commercial and open-&-commercial clusters scored high on the

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[34] One alternative approach to measuring the organisational mission is based on whether the scientist's research falls within the scope of patentable subject matter. This could be captured using the departmental means for the number of patent applications over the last year and the number of patent titles held. By using a departmental average, rather than just the individual's response, we would capture scientists who research patentable subject matter but do not necessarily apply for patents. This holds as long as we can validly assume homogeneity of research within departments according to patentability. When we clustered the data using these alternative items we found that 94.5 percent of scientists were clustered into the same cluster as the first method. Furthermore, we also found that the choice of clustering variables did not materially change the final regression results. Accordingly, in the analysis section, we present the results using clusters based on the first set of items only.

questions about the department's ethos with respect to encouraging the free exchange of information and dissemination of research findings at conferences. There was only a slight difference between these two groups. In contrast, scientists in the proprietorial-&-commercial environment were much more likely to report that scientists in their field are secretive and that patent is more important than publishing in peer-reviewed journals.

Predictably, the open-&-non-commercial environment was most likely to say that: there is no pressure from senior management to patent; they were free to publish or present inventions without reference to patenting; least likely to depend on funds from industry; and least likely to hold patents. Open-&-non-commercial environments are more likely to be drawn from the science and architecture faculties and least likely to be drawn from the medical and engineering faculties.[35] The open-&-commercial environment was midway between the two extremes with respect to the questions about the mission of the workplace.

Table 5: Cluster Characteristics, Summary

Cluster characteristic	**Open-&-non-commercial**	**Open-&-commercial**	**Proprietorial-&-commercial**
COMMUNITARIAN VERSUS PROPRIETORIAL CULTURE			
"Scientists working in my field of research are secretive" (=1) VERSUS "Scientists working in my field of research are very open" (=7)	5.897	5.109	3.798
"Publishing in a peer-reviewed journal is more important than patenting" (=1) VERSUS "Patenting is more important than publishing in a peer-reviewed journal" (=7)	1.400	1.876	3.762
"We are not encouraged to present our findings at conferences" (=1) VERSUS "We are encouraged to present our findings at conferences" (=7)	6.537	6.136	5.233
"We are not encouraged to share information on our research program with other scientists" (=1) VERSUS "We willingly share information on our research program with other scientists" (=7)	6.490	5.904	4.791
NON-COMMERCIAL VERSUS COMMERCIAL MISSION			
"We are under pressure from senior management to patent our significant inventions" (=1) VERSUS "There is no pressure from senior management to patent our significant inventions" (=7)	6.663	4.105	2.902
"We never disclose our significant inventions before filing a patent application" (=1) VERSUS "We are free to publish or present our inventions without reference to patenting" (=7)	6.717	5.095	2.323
Please estimate the proportion of funds your research department or laboratory receives from contract and commissioned research, and industry funds (proportion)	0.182	0.215	0.283
Research status: research-only versus research and teaching	0.392	0.377	0.523
"How many times have you applied for a patent over the past year?"[a]	0.055	0.151	0.580

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[35] This appears consistent with evidence from Germany and the UK (Haeussler and Colyvas 2011).

“How many patents do you currently hold as an inventor or patentee?” [a]	0.130	0.415	1.281
RESEARCH FIELD			
Medicine (proportion)	0.356	0.396	0.448
Science (proportion)	0.481	0.428	0.402
Engineering (proportion)	0.136	0.156	0.141
Architecture (proportion)	0.027	0.019	0.009

Notes: [a] This question asked respondents to circle a number 0, 1, 2, 3, 4, 5 and >5. In order to cluster, we require a numerical number, so we interpret responses of “>5” as equal to 7. n= 4,233

5.2 Modelling Changes in Choice of Research Projects

We modelled a scientist’s decision to change research project due to the presence of other researchers’ patents for each scientific environment cluster. The dependent variable – the degree to which the presence of patents affected scientists’ decision to change research projects, which we call *ChRes* – is modelled as a function of: 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*); and the degree of difficulty associated with negotiating with patent owners vis-à-vis permission to use a patented research tool (*TransactionCosts*). We also include a set of other background factors (*X*) – including age, gender, years since completing PhD, survey year and a dummy variable for each type of workplace.

The estimating equation for each scientist *i* is:

$$ChRes_i = \beta_1 LegalUnderstand_i + \beta_2 Experience_i + \beta_3 TransationCosts_i + \gamma_i X_i + \varepsilon_i \qquad (1)$$

To allow for the coefficients to vary by scientific environment and subsequently to test for differences in the coefficients (βs), we interacted each variable with the relevant environment dummy variable and estimated in a common equation. The dependent variable and the explanatory variables were constructed in the manner described below. For a complete description of the questions used in the construction of each variable, refer to Table A3 in the Appendix.

Dependent Variable. As mentioned, our dependent variable – *ChRes* – used 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. Although this question does not state it explicitly, we interpret a "major effect" as equivalent to the project being abandoned.

Explanatory Variables. To construct the variable *LegalUnderstand,* we averaged three statements 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. The three statements were: not-for-profit sector researchers need permission to use patented research tools and techniques if... i) that use is purely for research; ii) that use has commercial intent; and iii) the owner of the patent is a public organisation. Respondents could report "true", "false" or "unsure" for each of the three statements. We constructed the variable *LegalUnderstand* as the mean of reposnses which were coded as 3= "true", 2= "unsure", 1= "false".[36] A high factor score means the scientist thought permission was necessary, whereas a lower factor score means that the scientist thought it was not necessary or was unsure.

The variable *Experience* captures whether scientist's research project choices have been influenced by their previous experience with requests to use other researchers' patents. This 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. This gives us a measure of the scientist's experience with rejections. Note that we do not observe who the patent owner is in this instance – whether it was another academic scientist or a commercial firm presumably has an effect on whether the request is granted or not, but it is unobserved here. For our purposes, what is important is the actual outcome – whether the request was granted or not – rather than the determinants of this outcome.[37]

Finally, the variable *TransactionCosts* is constructed using responses to four statements about: difficulties getting information about methods from other researchers; difficulties getting data or materials from other researchers; difficulties negotiating with patent owners; and the imposition of publication restrictions. For each of these four statements, scientists were asked to

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[36] We explored a number of different ways of constructing this variable including coding the variable as a binary response: 1= "true", 0= "unsure" or "false". However, the results were robust to the different possible definitions, so we have presented the simplest one here.

[37] There are a number of different ways we could have constructed this variable – for example, we could have included separate variable for the number of times permission was sought and the number of times permission was granted, or included the two items as a ratio. However, our results were not sensitive to these different definitions.

rate the severity of the problems on a 1-7 Likert scale.[38] We constructed the variable as the mean of non-missing responses to the four items.[39] A high value for the variable *TransactionCosts* means these transaction costs are high.

When attempting to model this relationship, it is important to consider whether the explanatory variables we have identified are exogenous to the decision to change research project. There is a *prima facie* case for believing that some of our explanatory variables may be endogenous to the model. Consider the variable *LegalUnderstand*. This variable is related to 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.[40] This suggests that the direction of causality must be from legal understanding 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.

However, the respondent's views about difficulties obtaining information and materials, negotiating with other researchers for patent permission and the imposition of restrictions – which is captured by the variable *TransactionCosts* – may be endogenous since changing research projects is one way to reduce the angst associated with a particular research trajectory. Potential endogeneity requires us to use an instrumental variable and we chose the mean value *TransactionCosts* for all respondents in each department and year as a suitable instrument. The average departmental experience should be correlated with the individual's experience but whether an individual has changed his research should not affect the department's experience

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[38] The four items are collinear but are significant when included separately in the regression results.

[39] With regard to "missing" responses, we found that 26.9 and 22.7 percent of people did not respond to two transaction costs questions - "Negotiating with owners of patented technologies has been easy…" and "Patent owners have not placed any restrictions on the timing of our research publications...". We believe this was because they had never negotiated with patent owners. Over 90 per cent of the people who did not respond to these questions had not requested permission to license a patent in the previous 12 months. Since omitting these observations could bias the results, we tried several imputation methods including (a) inferring that the correct answer was that they had no difficulty at all; (b) imputing the answer from the other non-missing transaction cost items; (c) taking the mean of other respondents in their department. In the end, all of these approaches produced qualitatively similar results to using the mean of the non-missing items.

[40] It is possible that a scientist pursued a project, was sued (or threatened with legal action by the patent owner), which caused them to change their beliefs about their legal understanding and ultimately ended up with the scientist changing their research project. However, even in this case the chain of causation still runs from beliefs to changes in research projects rather than the other way around.

with transaction costs since the mean number of respondents per department is quite high (15.0 in the estimating sample). Hence, we argue that the departmental mean is a valid, exogenous instrument.[41]

We estimated equation (1) as both a pooled IV linear regression and a series of panel estimations. Pooling enabled us to test for differences in the estimates for the scientific environments. In each case, the regression is 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). Note that this clustering is not the same as the clustering command we used to get the three scientific environments.

6. Results

Table 6 presents the mean of the dependent variable and the three explanatory variables according to scientific environment. It shows clear differences in the dependent variable – those scientists in proprietorial-&-commercial environments are considerably more likely to have been influenced by the presence of patents, followed by those in the open-&-commercial environment. There are also clear differences in the explanatory variables with the two commercial clusters being most likely to believe that permission is needed. There was also an ordering of the transaction costs from open-&-non-commercial – lowest – to proprietorial-&-commercial group – highest.

Table 6: Variables used in regression by scientific environment, mean

Variables	**Open-&-non-commercial**	**Open-&-commercial**	**Proprietorial-&-commercial**
ChRes	1.579	2.227	3.259
LegalUnderstand	0.473	0.526	0.576
Experience	0.985	0.983	0.977
TransactionCosts	2.740	3.348	3.984

The results of the estimation are presented below in Table 7. Table 8 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. We found that there is a statistical difference between the estimated coefficients

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[41] Using a grouped within sample variable is a method used by Daniela Del Boca in labor economics.

for the three clusters – but only if we took the first three coefficients as a group. There was no statistical difference in the point estimates for triplet coefficients (at the 5 percent level). Gender and time since completing PhD were never significant and were not included in the final estimations.

Table 7, which presents both the nested IV regression and a series of three IV panel estimations (using the random-effects estimator), reveals a considerable level of consistency. Looking first at the constant terms, we can see that it is lowest for open-&-non-commercial and highest for proprietorial-&-commercial which suggests that work culture and mission do matter. Scientists' beliefs about patent law were a significant moderating effect on whether research direction was changed. While the proprietary-&-commercial cluster group were most likely to believe that formal permission was needed to conduct research (as shown in Table 6) they were also most sensitive to this belief. Although the difference in the coefficients was not statistically different across samples, the point estimate for the proprietary group was about 50 percent larger than the estimate for the open-&-non-commercial cluster. This result suggests that many 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 to "ignore patents". This observation is also backed up by evidence in the U.S. presented in Lei Juneja and Wright (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' choice of research projects.

There is no strong evidence supporting the view that recent refusals to use patented research technologies affects scientists choice of research projects. The variable in our model which captures this effect – *Experience* – is insignificant in all but one of the estimations. Transaction costs are a pertinent variable from a policy perspective since anecdotally it is regularly cited as a factor leading to inefficiencies in the patent system. According to Table 6, proprietorial-&-commercial scientists believe they experience the greatest level of transaction costs followed by the open-but-commercial cluster. Our regression results from Table 7 show that in addition, both of these commercially orientated groups are more sensitive to transaction costs than the open-&-non-commercial cluster. That is, these scientists' decisions about choice of research projects were also more sensitive to these costs.

The results on the control variables are also worth noting. As mentioned, time since PhD and gender were never statistically significant. However, the size of one's research team and age were significant. Specifically, the size of the team mattered for the two commercial groups – people drawn from bigger teams were more sensitive to third-party patents. This may be because larger teams, compared with smaller teams, are more engaged in commercial science even given the environmental differences. Haeussler and Colyvas (2011) provide evidence that team size (among German and UK scientists) is a factor also in the breadth and degree of scientists' commercial engagement. We also found that age mattered for each cluster – older scientists were more likely to report that they do not change projects (a finding that is consistent with Bercovitz and Feldman 2008).[42] Our results were most marked for older scientists working in the "newer" commercially orientated environments. It seems that there is a cohort effect on culture with the younger scientists in the commercial workplaces being more likely to compromise than their senior colleagues.

Table 7: Regression estimations: Dependent variable is degree to which changed research project because of other researcher's patents

	IV nested regression			**IV with random-effects estimator**		
Explanatory variables	**Open-&-non-commercial**	**Open-&-commercial**	**Proprietorial-&-commercial**	**Open-&-non-commercial**	**Open-&-commercial**	**Proprietorial-&-commercial**
LegalUnderstand	0.326***	0.358***	0.531***	0.310***	0.319***	0.509***
	(0.0868)	(0.0995)	(0.163)	(0.0854)	(0.0978)	(0.148)
Experience	-0.628	-0.474	-0.0683	-0.656*	-0.544	-0.567
	(0.498)	(0.338)	(0.472)	(0.377)	(0.340)	(0.447)
TransactionCosts-IV	0.246***	0.328***	0.313**	0.199***	0.296***	0.242**
	(0.0678)	(0.0853)	(0.136)	(0.0645)	(0.0872)	(0.116)
Ln(research team size)	0.0287	0.180***	0.259***	0.0343	0.163***	0.217***
	(0.0538)	(0.0530)	(0.0803)	(0.0475)	(0.0497)	(0.0710)
Age	-0.0589*	-0.134***	-0.131**	-0.0630*	-0.133***	-0.146**
	(0.0345)	(0.0423)	(0.0635)	(0.0367)	(0.0414)	(0.0630)
Constant	1.528***	1.534***	1.711**	1.707***	1.753***	2.625***
	(0.555)	(0.525)	(0.804)	(0.451)	(0.523)	(0.713)
Observations		4,316		1,273	1,691	1,119
Groups		3,234		963	1,213	844
R-squared		0.679				

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[42] Although other studies, such as Haeussler and Colyvas (2011), find that older scientists are more likely than their younger peers to commercialize science, this is not the same thing as claiming that they have changed the direction of their research.

The statistically significant variables noted above are not all of equal impact. The marginal effects reported in Table 8 reveal that of the three moderating factors, each cluster was most sensitive to variations in *TransactionCosts*. The size of the research team was the only other notable factor with larger teams in the commercial environments being more likely to have had their research direction affected.

Table 8: Marginal effects: Change to dependent variable due to a given change in the independent variable

Explanatory variables	**Change in independent variable from...to**	**Marginal effect** **Open-&-non-commercial**	 **Open-&-commercial**	 **Proprietorial-&-commercial**
LegalUnderstand	μ-σ cf. μ+σ	0.205	0.242	0.367
Experience	μ-σ cf. μ+σ	-0.392	-0.275	-0.125
TransactionCosts	μ-σ cf. μ+σ	0.762	1.382	1.952
Ln(research team size)	μ-σ cf. μ+σ	-0.002	0.309	0.708
Age (years)	26-35 cf. <26	-0.073	-0.103	-0.105
	36-45 cf. <26	-0.146	-0.206	-0.211
	46-55 cf. <26	-0.218	-0.048	-0.316
	>55 cf. <26	-0.291	-0.152	-0.422

Note: Uses coefficients from Table 6 columns 1-3.

6.1 Robustness check

As an additional check for possible endogeneity in the explanatory variables, we used the longitudinal properties to estimate test for the effects of lagged explanatory variables (from 2007) on the dependent variable (from 2009). There are 1,113 scientists who responded to both waves of the survey. These results reported in Table 9 support our findings. In column 1 of Table 9 – where we pool all 1,113 observations – we find that *Lag-TransactionCosts*, *Lag-LegalUnderstand* and *Lag-Ln(research team size)* are in each case positive and significant; experience is not significant; and *Age* is significant at the 10 percent level. In columns 2 to 4, where the sample is divided according to cluster, the significance of most variables falls, which we believe is due to sample size issues.

Table 9: Regression estimations: Dependent variable is degree to which changed research project because of other researcher's patents

Explanatory variables (lagged except for Age)	**All**	**Open-&-non-commercial**	**Open-&-commercial**	**Proprietorial-&-commercial**
Lag-LegalUnderstand	0.549***	0.184	0.529***	0.348
	(0.124)	(0.154)	(0.178)	(0.298)
Lag-Experience	-0.0787	-1.074	-0.778	2.556**
	(0.550)	(0.874)	(0.782)	(1.065)
Lag-TransactionCosts	0.217***	0.0817*	0.105**	0.116
	(0.0337)	(0.0461)	(0.0498)	(0.0813)
Lag-Ln(research team size)	0.214***	0.0166	0.145*	0.291*
	(0.0619)	(0.0816)	(0.0870)	(0.149)
Age	-0.0765	-0.0659	-0.0546	-0.157
	(0.0519)	(0.0643)	(0.0747)	(0.124)
Constant	1.222**	2.506***	2.222***	0.171
	(0.603)	(0.927)	(0.846)	(1.241)
Observations	1,113	320	490	282
R-squared	0.069	0.023	0.035	0.053

7. Conclusion

In this paper, we use data from a large sample of academic scientists in public research organisations to test for whether third-party patents lead them to change their choice of research project. This potential externality has largely been ignored in the literature up until now. Our results suggest that while scientists are affected by the presence of patents, those working in workplaces with either a proprietary culture or commercial mission were most likely to be influenced. We also tested for the comparative influence of past negative experience with patent owners, beliefs about the law, and transaction costs, and found that the latter had the largest effect.

The traditional Mertonian view of science holds that there are *a priori* reasons to argue that the impediments to free choice of research project may come at some cost. The uncertain and non-linear nature of scientific progress can mean that sometimes that solution is not found through what would seem to be the most direct route. A classic example is the CSIRO Ngara wi-fi technology which is derived from the seemingly esoteric realm of radio astrophysics but is now the ubiquitous wi-fi technology in homes around the world. In uncertain environments, the social cost of risk may be minimised by spreading it across many different scientists work on a problem simultaneously. Countering these effects is the boost to investor confidence that property rights gives downstream investors. Without these rights, or their aura of protection, some ideas would not make the transition from the lab to the kitchen table.

This paper is part of an ongoing project to monitor and analyse changes with the research community with respect to both the incursion of property rights and the community's metamorphosis from teaching-based to industry-focused activities. Apart from the need to replicate our findings in other jurisdictions, there are two significant areas where more empirical work is needed before we can start to make clear statements about the welfare implications of this shift. The first is the on whether an end-use or commercial focus has a beneficial effect on the diversity and direction of research,[43] and the second is the magnitude of the effects of property rights on downstream investment. In a related paper[44], we estimate an upper limit for the latter, but much more work is needed in this vein before we are close to identifying a "stylised fact".

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[43] Huang and Murray (2010) discuss the role of experimentation in minimising the costs of uncertainty not only for the benefits of exploring options but also in enhancing the subsequently productivity of scientific knowledge.

[44] Webster and Jensen (2011).

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Appendix

Table A1: Response rates, by Wave, percentages

Position	Replied	Return to sender, or ineligible[a]	No reply	Total	Number surveyed
Wave 1 (2007)					
Professor/head	31.9	9.6	58.6	100.0	2,056
Senior researcher	28.8	16.5	54.7	100.0	2,929
Junior researcher	32.3	18.0	49.7	100.0	4,234
Pre-PhD	30.8	15.9	53.3	100.0	334
Administration	20.5	6.8	72.7	100.0	44
Total	31.0	15.6	53.4	100.0	9,597
Number	2,977	1,498	5,122	9,597	
Wave 2 (2009)					
Professor/head	18.9	8.4	72.8	100.0	2,056
Senior researcher	16.6	10.6	72.8	100.0	2,929
Junior researcher	14.3	16.3	69.5	100.0	4,234
Pre-PhD	14.7	14.4	71.0	100.0	334
Administration	18.2	15.9	65.9	100.0	44
Total	16.0	12.8	71.2	100.0	9,597
Number	1,536	1,126	6,835	9,597	

[a] This includes a small number of scientists (n=68) who asked not to participate in the project after they were sent a questionnaire in Wave 1. They were not sent a questionnaire in Wave 2.

Table A2: Mean of items from first and subsequent mailouts

Item	*Mean first mailout*	*Mean subsequent mailout(s)*	*t-statistic (difference of means)*
ChRes (Dependent variable) – pair of opposing statements (1…7)			
Other researchers' patents have no effect on which research projects we choose to undertake (=1) VERSUS Other researchers' patents have had a major effect on our choice of research projects (=7)	2.257	2.281	-0.447
LegalUnderstanding – proportion answering "true"			
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use is purely for research.	0.438	0.431	0.434
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use has commercial intent.	0.704	0.700	0.306
Not-for-profit sector researchers need permission to use patented research tools and techniques if the owner of the patent is a public organisation.	0.426	0.403	1.491
Experience			
How many times have you sought permission to use someone else's patented technology over the past year? (assumes >5=7)	0.181	0.153	1.529
How many times was permission granted? (assumes >5=7)	3.017	3.093	-1.409
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	3.017	3.093	-1.409
We have had no difficulty obtaining materials (data or research tools)	3.173	3.323	-2.803***

from other researchers VERSUS Getting materials (data or research tools) from other researchers has been an obstacle for us			
Negotiating with owners of patented technologies has been easy VERSUS Negotiating with owners of patented technologies has been difficult	4.090	4.096	-0.095
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	3.411	3.483	-0.993
Commercial Orientation			
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	4.525	4.634	-1.678
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.	4.854	4.793	0.917
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			
Workplace Culture – pair of opposing statements (1…7)			
Scientists working in my field of research are secretive VERSUS Scientists working in my field of research are very open	5.002	5.006	-0.083
Publishing in a peer-reviewed journal is more important than patenting VERSUS Patenting is more important than publishing in a peer-reviewed journal	2.178	2.292	-2.142**
We are not encouraged to present our findings at conferences VERSUS We are encouraged to present our findings at conferences	6.040	6.002	0.814
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	5.826	5.756	1.598

Table A3: Mean and standard deviation of items used to construct the variables

Item	***Mean score***	***Standard deviation***	***Scoring coefficients (factors)***
ChRes (Dependent variable) – pair of opposing statements (1…7)			
Other researchers' patents have no effect on which research projects we choose to undertake (=1) VERSUS Other researchers' patents have had a major effect on our choice of research projects (=7)	2.267	1.719	
LegalUnderstanding – proportion saying "true"			Alpha= 0.7793
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	0.3725
Not-for-profit sector researchers need permission to use patented research tools and techniques if that use has commercial intent.	0.7014	0.4577	0.2234
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	0.4092
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	