Regimes of Ordering: The Commercialisation of Intellectual Property in Industrial-Academic Collaborations
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BRIAN RAPPERT & ANDREW WEBSTER

This paper examines a diversity of regulatory mechanisms and negotiation processes involved in attempts to commercialise university research which provide direct and indirect means of linking the activities of individuals and organisations in the acquisition and exchange of commodified goods. The key question addressed is how is an activity that is always uncertain -- the production of knowledge -- 'packaged' by intellectual property management and intellectual property rights so that it is controllable, commodifiable, and enters into exchange relationships. This paper addresses the acquisition and stabilisation of proprietary claims to knowledge between public and private organisations by considering a detailed case of a university spin-off and in doing so raises a number of more general issues about the translation of knowledge.

The commercialisation of the public sector research base, and in particular academic research, has been a continuing preoccupation with policy makers and academic policy analysts around the world. Given the strong state-driven emphasis on the goals of this activity -- typically characterised as improving national competitiveness and quality of life -- most analyses attempt to stress the benefits of commercialisation(2). Many of these analyses focus on the way collaboration between academia and industry can be enhanced by breaking down barriers between the supply and demand sides of the innovation system. Typically, new mechanisms for technology transfer are advocated(3) through which university science can be more effectively exploited. Rarely, if ever, however, do these analyses explore the sort of transformations of knowledge required in the commercialisation process.

This paper takes this as its central focus, and suggests how we might understand the process of acquiring and stabilising proprietary claims to knowledge, and so the way that knowledge takes on an 'appropriable' form and status. In doing so it considers the diversity of regulatory mechanisms and negotiation processes involved in attempts to commercialise university research which provide direct and indirect means of linking the activities of individuals and organisations in the acquisition and exchange of commodified goods.

A key feature of the commercialisation of knowledge is the acquisition of and control over it as 'intellectual property' (IP). Hence, the IP generated in universities has been central to debates over the successful commercialisation of the public sector research base, so important to the language of wealth creation today. This has particularly been the case in many countries since in the mid-1980s with the devolution to universities of the responsibility for managing their own intellectual property rights (IPR). Yet there are clearly important questions to raise about who pays for and who profits from publicly funded research which, in turn, reflect fundamental concerns over conflict between the requirements necessary for the commercialisation of knowledge and the public obligations and responsibilities of university staff. In liberal capitalist states the public sector is typically removed from commercialisation or at least outside of the circuit of the production of commodities. Open science, often equated with public sector science, is supposed to produce public goods which are freely available. Yet, the recent push towards the commercialisation of public research both blurs the boundaries between the public and private sectors and creates tensions between them (4).
While a number of researchers have examined these general tensions in the university context and those associated with IPR issues in particular (5) these studies typically stop at the point where knowledge moves into the commercial setting. Without understanding the processes related to producing and then appropriating IP we will never be able to understand fully the tensions, uncertainties, and conflicts that influence commercialisation. Moreover, without this understanding we would be unable to determine the 'income-generation' potential as well as limits of commercial activities. To do so requires looking at not only changes within the university, but the wider context or environment in which that knowledge is taken up. It is necessary to see commercialisation in terms of socio-technical, organisational and political dynamics which enable social actors to stabilise and secure knowledge in ways that will render it appropriate and exchangeable. We must look, in other words, at the ways in which a structure of appropriation is built by social actors.

At a general level, knowledge, and scientific knowledge in particular, has always been in a fairly simple sense a "commodity." That is to say knowledge is often a scarce resource that meets particular needs or wants and so can be bought or traded. Yet, at such an abstract level many of the complexities that lie behind this trading are missed, not least the way in which the use and exchange-value of knowledge has to be established in the first place, and not merely 'once and for all', but on a continuing basis. Moreover, knowledge is also collectively embedded in a mesh of social relations - such as research networks - so the process of rendering scientific knowledge a commodity owned by just some and not others is not straightforward.

In this paper we argue that the construction and maintenance of knowledge as a commodity is a process of reducing the complexities of socio-technical relations to fix them in a temporary (though always inherently unstable) 'regime of appropriation'. Intellectual property management and intellectual property rights can be seen as important ways of addressing the uncertainties associated with commercialisation. This is particularly true of patents: patent monopoly rights rest not simply on priority claims to being 'first' with an invention but also on claims which demonstrate this through their being distilled into the most basic, essential aspects of the inventive step which, then and only then, anyone 'skilled in the art' could reproduce without difficulty. Precisely because they have been simplified in a codified and accessible way can they be made appropriable. So it is important to ask how is an activity that is always uncertain -- the production of knowledge -- 'packaged' by intellectual property management and intellectual property rights so that it is controllable, commodifiable, and enters into exchange relationships?

Our paper is based on a UK study of the intellectual property dynamics of university spin-off companies (USOs) and a matched group of small and medium enterprises as well as on an earlier project dealing with IP in universities. The next section lays out a conceptual framework for understanding appropriation terms of the notions of 'regimes of appropriation' and 'regimes of governance'. The third section then reflects on and problematises policy initiatives to encourage commercialisation and harness IPR in universities. Following on from this discussion we discuss whether university spin-off firms provide a more sensible route through which the uncertainties associated with the commercialisation of university research can be managed. The fourth section presents a detailed case study of a USO commercialising software developed in the university. The final section offers some conclusions based on the approach adopted here.

Developing a framework

Three main areas are considered in examining the production and reproduction of knowledge as a commodity: first, the process of appropriation through which social actors capture economic rents from innovation; secondly, the local situation which frames the way academics are encouraged to pursue commercialisation - what we call the local regime of 'governance'; and thirdly, the 'ordering' strategies and procedures whereby actors attempt to manage the context through which knowledge is produced, exchanged, and disseminated.

Regimes of appropriation

Firms attempt to exercise control over goods, in part to ensure the appropriation of returns. In thinking about appropriation we want to begin by drawing on, and later expanding, a useful conceptual framework develop by Teece (6) for understanding how firms profit from technological
innovation. Teece’s framework consists of three major elements: regimes of appropriation, design paradigms, and complementary assets. The latter refers to the range of specialised and generic capabilities or assets necessary for successful innovation. The element of design paradigm draws attention to the life cycles of products and (mass market) industries by considering whether or not an established set of designs for an innovation has emerged.

While not ignoring these elements, we wish to focus on the first element identified, the regime of appropriation. According to Teece the regime of appropriation “refers to environmental factors, excluding firm and market structure, that govern an innovator’s ability to capture the profits generated by an innovation” (7). The two major dimensions of this are the legal framework of IPR protection and the nature of the innovation involved, including whether or not it is a product or process and the degree of codification possible. The ‘tightness’ and so success of a regime of appropriation thus depends on the legal protection offered and the ease of imitation (8).

In this paper we will examine attempts at appropriation by a university spin-off firm producing innovative software, where the most relevant form of IPR protection is copyright. As innovations, both software and databases are protected by copyright. Copyrights differ from what many regard as a stronger form of IPR - patents, in a number of ways. Being awarded a copyright does not require meeting the criteria for patents (e.g. novelty) or necessitate engaging in an elaborate application process and no register of copyrighted material exists. However, though easier to obtain, there are limits to the protection copyrights afford. Patents prevent others from using or making the same invention even if they come across it independently. Copyrights, on the other hand, protect the original expression of an idea, rather than the idea itself. Needless to say, that distinction is not always easy to make. Infringements are more uncertain and difficult to detect and thus copyrights are limited in their utility or protectiveness in terms of granting rights to individuals or corporations.

Nevertheless, it would be inaccurate to say that copyright is of little consequence. Rather it is necessary to conceptualise forms of IPR - such as patents and copyright - differently, to attend to the diversity of mechanisms (both direct and indirect) involved, and the way in which they mediate the concerns of academics, government and firms. Copyrights still signal ownership and in doing so exclude some from ownership. Whatever protection this offers from imitation, the demarcation of ownership can be vital in making contact with financial institutions and other firms and they help justify a particular distribution of equity between a university and the researchers. While copyrights are granted automatically and do not require the same level of devolved responsibility as patents, they still require effort to protect and exploit. As we shall see in our Case Study, the firm in question seeks to build a regime of appropriation around its software through a range of strategies which include formal copyright, even if the necessity for such a range reflects the weakness of this form of IPR.

Regimes of governance

The commercialisation of university research (e.g., through licensing new technologies) is rarely a matter of imposing particular practices on researchers. Obviously changes in funding policies and policy prescriptions can influence the activities of researchers, but not in a straightforward manner. Rather these developments are about harnessing autonomy and enterprise in a local setting which - whether involving commercialisation or not - displays a complex mixture of academic freedom and institutionally driven goals. This paradox is illustrated by the way in which university managers carefully constructed development ‘plans’ and targets (for recruitment, income generation, research ratings etc.) presume considerable risk-taking by academics on the ground.

Miller and Rose(9) draw on concept of “governmentality” (10) in order to examine the diversity of regulatory mechanisms and techniques of manipulation and negotiation which provide an indirect means of linking the activities of individuals and organisations. At a local level, individual researchers face numerous authorities (e.g. departmental politics, research assessments, financial constraints, administrative practices, fellow peers) to which they must respond and which govern their lives. So, in considering the enterprising activities of academics we need to make sense of them in terms of a particular pattern of regulation and governance that the academics are subject to, but through which they also build their positions qua academics.
When academics do engage in activities that aim to commercialise their work they expose themselves to the authority or governance of the commercial market. Taking a patent out, for example, opens up one's knowledge claims to a new form of scrutiny, surveillance and evaluation (11): the awarding of patents provides a basis for rendering research calculable by providing a means of comparing spatially and substantively diverse knowledge claims. It does this in two ways, first of all by making the value of research outcomes subject to 'wealth-creating' indicators; secondly, in applying for a patent, knowledge claims are measured against the current state of the art (or 'prior art') in the intellectual property market. In short, scientists must accommodate new forms of evaluation and governance foreign to the regime of governance within which they conventionally find themselves (10).

This might lead to unforeseen consequences for the academic researcher: for example, patenting may be likely to mean not only that research goes down a particular route, but also that additional experimental work will be needed in order to build up a portfolio of IPR. At the same time, the more this happens the more possible it is that academics become more open to further control and direction by university management keen to see income generation. Though often indirect (compared with the situation of research scientists in private firms) this control allows some researcher freedom, but in a constrained field of possible actions.

However, as we will show, universities are complex systems whose component parts often resist efforts to steer matters in particular directions. Researchers (as well as industrialists, administrators, and others) make calculations about their interests and their conduct in response to diverse economic, technical, cultural, and social (e.g. peer group) authorities. Again, as our Case Study below will show, the principal actors involved find themselves handling multiple authorities as they attempt to build up their firm. As a result, they are subject to, while simultaneously seeking to develop control over, a complex regime of governance.

These two concepts of regimes of governance and regimes of appropriation are, as might be expected, interlinked. Thus, from the perspective of each actor, particularly in collaborative projects where claims to knowledge are negotiated, ensuring proper appropriation takes place requires making sure others recognise and respect specific definitions of who owns what. This conjunction between the two regimes is related to our third theme in this conceptual framework, viz. the 'ordering' strategies and procedures whereby actors attempt to manage the context through which knowledge is produced, exchanged, and disseminated.

**Ordering and Stabilisation**

The processes of ordering of knowledge can be seen in terms of an ordering of social relations between knowledge users and producers, as that it thereby involves an exercise of power. Social theorists have grappled with the question of how to understand power for many years of course. But Law has suggested that the crucial question we should ask is “how it is that relations are stabilised for long enough to generate the effects and so the conditions of power” (13). Following in a tradition of sociological studies of science and technology, we can use Law's approach to explore the ways in which social actors try to stabilise and control the relations they have with the diverse range of actors and artefacts to which they are linked in academic-industry networks.

Stabilisation is expressed in the changed status that knowledge has - codified, delocalised, appropriable - and also in associated relations, structures and institutions. These provide the context through which knowledge is produced, exchanged, and disseminated and the 'conditions of power' these processes reflect. That is, stabilisation is a key process related to the ordering of organisations and people, empowering some actors more than others.

Stabilisation in this context is most easily secured when knowledge-claims are progressed through a regime of appropriation and regime of governance which are linked together and embedded in a particular institutional 'ordering'. Publishing papers and appropriating symbolic capital via the peer review process in academia is a simple example of this process at work. Where we see members of a particular institutional 'ordering' pursuing appropriation strategies in ways that compromise, or challenge established structures, stabilisation of these claims is more problematic, as, therefore, is the sense in which they can be effectively exploited.
In universities we can see that the commercialisation of academic research has created new problems for the translation of academic knowledge-claims into commercialised knowledge-claims. This is because the existing regimes of appropriation and governance through which the stabilisation of academic research normally operates do not sit easily with the commercialisation of science. This problem of translating and stabilising knowledge across different regimes is not peculiar to the commercialisation of academic science. So, for example, we can see that firms in the private sector that have established new markets for their products can run up against the demands of very different regimes of governance outside of the market per se, such as new specifications laid down by international standards authorities or regulatory requirements of health agencies. Both these have hit the appropriation regimes of IT and pharmaceutical/biotech firms respectively. The options firms face here are either to modify and re-codify their knowledge claims to meet these demands or to influence the regime of governance directly: typically firms do both in order to re-stabilise their markets. Monsanto, for example, has used both strategies in its attempt to secure its European market for BST-derived milk.

It is important to recognise, of course, that the process through which some are empowered and through which 'knowledges' can be made appropriable in commodity form, is never straightforward, and is never simple to secure. The stabilisation of knowledge claims requires that they can be sustained and accepted across a range of different recipients and/or buyers. Some commentators hint at this in their examination of the translation of knowledge claims from one constituency of interests to another: for example, Molina's notion of 'sociotechnical alignment' between different knowledge constituencies implicitly considers processes of stabilisation(14).

The legal system plays an important role in the stabilisation of knowledge claims. It is a system which specifies the ownership of intellectual property and which "provides a method of discursively stabilising answers"(15) to questions such as who invented what and what rewards should they derive from their efforts. So, we can examine how knowledge generated in research eventually becomes "solidified" into artefacts which have a commercial value and which belong to some rather than others. Again, our Case Study shows how a particular firm has sought to stabilise its intellectual property across a growing range of knowledge users - other academics, the university, other firms - where to do so means that the firm has had to order the terms on which the property is used.

Before moving to the case study itself, let us look first at the university as a site in which one can see the arrival of new ways of 'ordering' knowledge production and use, ways which have encouraged the creation of university spin-off firms.

**IP 'ordering' within universities**

Public funding for university research has become more and more dependent on the perception of whether it will make a direct contribution to the economy, and the anxiety felt over the need to exploit scientific research has contributed to the formation of a number of commercialisation policies.

This - and the reduction of funding for the public sector research in the UK-has forced public sector institutions, especially universities, to undertake activities which either attract industrial funding or generate income. In part responding to government policies, universities have engaged in various organisational innovations by which they become involved in the construction of exchangeable goods, the encouragement of exchange activities (e.g. licensing, etc.) and the establishing of exchange promoting institutions (e.g. innovation centres). In short, we are beginning to see a shift from a grants to an exchange economy in higher education. This has required new institutional orderings and modified regimes of governance that can manage and reward so-called academic enterpreneurialism.

Property rights can take a variety of forms, both statutory - such as copyrights or patents - as well as non-statutory such as priority claims over publication, or reputational credit over a particular discovery. Social scientists have typically focused on this second variety of intellectual property in the scientific community: for example, Latour and Woolgar speak of the symbolic and material capital resulting from a scientist's successful investment in his or her "credibility cycle". As they say with regard to investing capital in such cycles(19), "In this respect, scientists' behaviour is remarkably similar to that of an investor of capital. An accumulation of credibility is a prerequisite to investment. The greater this stockpile, the more able the investor to reap substantial returns and thus add further
to his growing capital." Increasingly today, however, scientific capital is taking a more commercial form through the growth of patenting and other activities in universities and government research laboratories. In 1985 UK universities were given the right and responsibility to exploit their intellectual property by securing property rights to ensure publicly funded work was transferred to the private sector. From the government's perspective, the devolution of rights from the British Technology Group to universities was intended to both help universities generate income for themselves and contribute to national wealth creation.

Academic 'entrepreneurs' are encouraged to secure formal rights on their intellectual property as a key step towards the successful commercialisation of their research. The new institutional vehicles which facilitate this process - such as industrial liaison offices and incubator firms - create new regimes of appropriation and valorisation. But there has too been an attempt to relate these new regimes of appropriation and governance to that found traditionally within academia: hence we have seen that the Higher Education Funding Council has requested that patents held by academics should be regarded as evidence of 'quality research' in the national Research Assessment Exercise, and have, thereby, some equivalence to conventional academic output such as journal papers. Patents held by academics seem, therefore, to able to provide evaluative measures in two distinct regimes of appropriation at the same time.

In fact, the translation does not work so straightforwardly (Webster and Packer, 1996). It is important, first of all, to recognise that universities have not found it easy to construct new regimes of governance that can handle commercialisation of research. In an in-depth study of nine universities' industrial liaison offices Harvey(16) found these universities IPR policies confused and often ignored by academics - it appeared there was as much disorder as order from the perspective of those attempting to instil a systematic order.

Secondly, the construction of a regime of appropriation in universities in order to promote technology transfer and 'wealth-creation' may in the medium to long term have a constraining effect on the overall rate of transfer from the science base to industry. The filing for patents in universities may unintentionally compromise the commercial potential of research for the private sector. This can happen as the securing of patents positions the university as a potential competitor to private firms or acts as an obstacle to future product development if the patent coverage is poorly framed or is filed prematurely(17). Premature filing can be understood in terms of a failure to codify the patent claims properly, since a patent is described as 'premature' when its scope is regarded as drawn too narrowly to allow for proper exploitation of the work it covers. More fundamentally though, the focus on IPR can create tensions by shifting universities from being relatively open suppliers of ideas to industry to being more closed and more costly sources of information.

Thirdly, the failure to establish stable structures within which the commercialisation of academic science is to be secured can have a number of unintended effects. For instance, scientists in academic settings can utilise patents that they file to frustrate and not only to encourage commercial efforts. As one interviewed molecular biologist said:

Our work is definitely not commercially oriented, it is academically oriented, but every new thing we find is going to be latched onto by the big drug companies, and they might prevent us from carrying on. If we feel this is a big prospect we will take out patent cover.

Certainly this type of "vindictive patenting" practice(18), though rare, is not the sort of practice government policies on IPR intended to promote. The promotion of property relations in university research destabilises pre-existing relationships, attitudes, and the relations of production and thereby provide means for academics to subvert policy intentions or corporate agendas.

The unintended consequences of social action with respect to such things as "vindictive patenting" shows the limits of 'ordering' and stabilisation within a commercially-oriented universities. In some ways, at least from the perspective of the frustrated academic, the resistance expressed by "vindictive patenting" is a sort of 'disordering' or at least an attempt to redefine the terms on which patented knowledge-claims are to be used (i.e. not for exchange value in a specifically commercial sense, but to protect an academic arena which is being destabilised by competitive/commercial pressures from elsewhere).
University spin-off firms

Given our argument above, it is perhaps not surprising that the problems with stabilising commercially exploitable knowledge claims via conventional university structures leads some to move towards university spin-offs as an effective vehicle for this, which, in theory, will enable the construction of a different institutional framework (the private firm) whose structures and operating procedures are geared precisely towards commercialising knowledge (know how embodied in products etc.).

In recent years there has been a growth in the number of firms that have been spun out of universities(20) sometimes through action at the centre, sometimes through individual initiative. USOs prove an interesting focus for analysis in the context of concerns over the privatisation of university knowledge. On the one hand, some portray USOs as fairly unproblematic means of commercialising "public" research or at least a means of rationalising the commercialisation process. Commercial activities are "hived" off into separate settings from those of the university lab. But this tidy separation is often rarely achieved - or indeed sought - in practice, since many USO managers seek to retain some relationship with the university departments from which they sprang. The formation and perhaps the operation of USOs is a delicate process where the parties involved have to negotiate the boundaries between what can be spun-off and what should remain as the intellectual stock of the university. This is especially problematic where the proposed spin-off relies on scientific methodologies or techniques which are embedded in the research culture of the university laboratory.

Are, then, USOs better placed than other forms of institutional ordering to handle possible institutional tensions? Rather than discussing this in terms of general patterns of practice among USOs, we will consider one case study. This detailed case study approach will show us some complexities that are missed in more generalised studies.

USO Case Study

The case study describes the formation and development of a USO which we shall call ITDesign (ITD)(21). ITD's origins lay in a methodology developed by one of its co-founding academics, Professor Wood, for selecting engineering materials. The methodology involves a series of graphic maps which enable users to scan across a wide range of materials for particular properties and then optimise a combination of properties. Initially the maps were made freely available to university students as well as professional engineers.

In 1986, Wood was approached by an engineering colleague, Dr Steele, who had a background in teaching related software. Steele suggested developing a software based version of the then paper-based graphs. Subsequently, a couple of prototype systems were developed with collaborating students. The fairly intensive level of specialised computer programs required for producing the programme meant Wood and Steele had to seek funding to continue further. Over the next four years a first stage commercial product was developed with the aid of a trust grant and a forgivable loan from university resources. Steele started selling the product direct from his departmental office with the help of the university industrial liaison officer (ILO), who provided a facility for sending out disks and who did a small proportion of the distribution in return for a percentage of sales.

In the first two years Wood and Steele licensed about £80,000 worth of programmes, almost exclusively by licensing the software “cheaply” to academics for teaching and research purposes. The academic credibility of the founders (e.g., a number of major textbooks in engineering science open with their maps) lent a credibility to the commercial product and knowledge of the field gave them a good sense of the potential market. At this time, Wood and Steele had one or two student research assistants working in the engineering department, being paid by income from sales that went through the ILO and licensed through UniEnt, the universities’ commercial exploitation unit. This income was enough to allow them to develop a ‘Windows’ version in 1991. Today, the firm employs five people and sells the initial software product and a Windows version with a combined sales of about £150,000 per year. Essentially, the University acts as a contractor doing the development work for which the company pays. Wood and Steele are now looking to move the operation of ITD off the university’s grounds and have hired a full-time marketing director.
Despite the ILO facilitating the development of ITD, Steele and Wood confronted a range of conflicting messages from different sections of the University. At the centre, the University is one of a number of major universities which takes a laissez-faire approach to the ownership of university generated IPR. As Wood explained, "the response you get when you try to tackle these questions [about IPR] is that they do not want to know. 'Go ahead and do but do not tell us.'" The muddled IPR policy left Wood and Steele in an uncertain position since both intended to retain their academic posts but did not wish to stir up ill-feeling among colleagues and students about their commercial activities. At the level of department, this in turn related to the 'ambiguous' view it held towards the establishing of USOs. On the one hand, both founders talked of the government pressures placed upon them and their department to provide useful outlets for their work. But they also told of an undercurrent of feeling which discouraged such activity because it distracted from educational and research roles of the university and raised a potential conflict of interest.

Steele initially had thought of producing the software in the Engineering Department and finding another firm to do the selling and distribution, with any income coming back to a small in-house company just doing development. But the attempt to link with a larger firm and a venture capital firm failed: the venture financiers wanted to co-commercialise other departmental products and services. Wood and Steele then decided to spend a small amount of money on legal expertise and set up ITD. A major impetus behind the establishment of ITD was the department's unwillingness to accommodate computer programmers who were neither members of staff nor students: here the university's structures and its associated regime of governance were incompatible with the firm's needs.

Initially the copyright protection on the software was shared by the university and the two founders who then assigned it to UniEnt which then transferred all rights to ITD. In exchange for giving up ownership, the university took a percentage of equity in the company and the rest is shared by Wood and Steele. The process was not, however, without its difficulties because Wood's post is not funded by the university, but an endowment from an external Foundation. He had to convince the Foundation to waive their rights to his work.

This situation is complicated further because at the academic level the material selection process is a major part of the work of a Research Council funded research centre at the University. Thus a number of different funding sources - the university, the Research Council, the Foundation and the firm itself - each with different policies towards IPR, were implicated in the development and appropriation of ITD's software. In order to minimise complications deriving form this blurring of funding sources, a conscious attempt was made to separate public and private money. Throughout the development of the software, the University received overhead costs and UniEnt was paid for the services it provided. Formally the development of software was done independently of Research Council or University funding. The money came from ITD itself or the initial grants. Wood noted, however, the difficulties of drawing boundaries between the 'public' and the 'private' in that the research done in the academic context on materials has fed into the background knowledge necessary for ITD's programmes. While the results of publicly funded research are published, there are spillovers into the commercial work of the USO.

The problems of ownership and control over the firm's intellectual property that result from the mixing of funding sources have been complicated further by recent developments involving a private funder of the research centre. A major Japanese company gives £100,000 a year to the research centre and as part of this funding they have undertaken collaborative work with Wood on the materials selection for "green technology" to use in electronic goods. At the end of the collaborative project, the company wanted to take out a joint patent application on some of the completed design work as well as including aspects of the materials selector methodology. Wood felt this was an unjustified attempt by the company to capture a wide scope of his research. The Japanese responded that they did not want to claim something unfairly, but in the Japanese market it was standard practice to patent as widely (and as often) as possible. The number and scope of patents plays a key role in the reputation of industrial researchers. But Wood still protested and eventually the Japanese agreed to restrict it to the specific technologies used for the new electronic goods.

Although the copyrights on the programmes allowed for the legal transfer of products into ITDesign while ensuring the University received a share of the commercial rewards, copyrights were seen to
provide little real protection in the commercial arena. The firm, like other companies, faces a variety of challenges in the market from other firms but also has special problems because of its location in an academic setting. Because of these the firm finds it difficult to secure a stable regime of appropriation. What does this mean?

First of all, there is the possibility that others will develop independently a programme based on an alternative way of doing the same thing. Though computer programmes for selecting polymers or metals have been around for quite some time, none of them cover all classes of materials as does the ITD programme. A USO elsewhere did try to market one such material selector, but went into receivership.

Secondly, there is the threat of large firms coming in and reverse engineering the programme. This was considered a real possibility and, given ITD’s size and resources, it would never be able to challenge a larger firm if they were seen as infringing on ITD’s rights. In fact, Wood alleges that a version of software for selecting polymers developed by a large software organisation includes information taken directly from his programme. In this case though the software costs ten times as much as ITD’s and is aimed at a different audience.

Thirdly, given the quasi-academic status of the company there are even potential worries about competition from within the university system. An academic centre in France contacted Wood about a materials programme they had written and admitted ‘pirating’ ITD’s database information on materials. Paradoxically perhaps, the French group told Wood that they were informing him of this in order to maintain ties. Subsequently, the two groups did in fact collaborate further and decided to start a joint (academic) research project and made a commercial arrangement whereby if the French partners license those databases ITD receives a royalty on them. Thus the academic peer system involves relationships of trust which spill over into commercial activities, and is an interesting case where it appears possible to blend distinct regimes of appropriation, or at least to translate the benefits of one - ‘academic trust’ - into those of another - royalty income.

Overall, Wood and Steele felt ITD’s best chance of securing their place in the market came from staying ahead of the competition by continuously adding value to their programs while maintaining a price that academia could afford. A number of factors are involved in staying ahead. The software does not stand alone. All sorts of other materials go with it: a best-selling textbook, case studies, and series of test problems which increase the educational value of the software. This package approach, however, does work to their disadvantage when selling to non-English speaking countries because of the cost of redoing everything. At the same time, Wood and Steele felt that their credibility established in academic setting gives assurances about the quality of this package.

The methodology underlying the software is quite highly developed and has generic use. Prototype versions have been developed which allow for the selection of the optimisation of manufacturing processes (e.g., machining, drilling) and components of bicycles. Now ITD is looking to expand the product range of the material selector, particularly aiming for industrial users. A two fold strategy is being adopted to make the interface less academically orientated. At present, users have to work out their design criteria, with ITD’s methodology, and ask the programme to generate those criteria. The goal is to reduce the complexity of this process by establishing menus of standard design cases. However, while this sort of simplification makes strategic sense, the potential to write generic menus for industry is limited in that while universities rely on similar specifications, no two industrial users have the same requirements. The adaptations needed for meeting the highly specific demands of industrial users require long, labour-intensive programming. The variable geometry of the market means, therefore, that this simplification strategy will never be fully successful.

In response, as a second strategy, ITD is developing a software system which enables people to put their own data into the system, rather than solely relying on existing databases. While the methodology underlying the software is generally recognised as superior to anything else, the data used is more restricted than in industrial programmes, which make use of insider proprietary information held by companies or trade organisations. This adaptation allows companies to make use of their in-house data and view it by using the basic material selector system. So, firms can compare different suppliers, compare themselves to competitors, tailor the system to compare standard products, and even trade in databases. Wood and Steele are trying to establish a flexible data format
whereby firms would use ITD's standard data format in order to then sell on these databases, with a percentage of sales from these databases going to ITD. This may well prove more successful in the longer term, since the simplification strategy relies much more on ITD designing its programme in such a way as to be translatable into a broader range of user databases.

Even here, though, the firm faces new risks which can destabilise its regime of appropriation. Thus, on the one hand, the firm must guard against other companies placing their name on databases and then undercutting the price. But on the other hand, ITD prides itself on the quality of its data and much of its credibility rests on it. So, when others make modifications to the data and sell it on, ITD does not want to be responsible for them. As Steele explained,

We have a bit of difficulty in saying "feel free to copy our materials, but you can not make a big database and sell it [without our permission] though feel free to use some of them. On the other hand if you do use some of them we do not take responsibility for the data anymore."

These difficulties have been responded to by techniques of surveillance in its wider business environment in order to maintain its means of appropriation 'at a distance'. These techniques help to establish a regime of governance in the market which 'orders' or controls others' use of ITDs intellectual property. For example, one technique is a tracking system within the program which records the materials which originated with ITD and which will say that if a database contains more than 10% of ITD originated data it is not for resale without a royalty going to the firm. In addition, it is necessary to ensure that while these materials are tracked in a modified database, they are no longer identified with ITD because they do not want to be responsible for them if they are modified. An identification system is being devised which will only allow ITD to know where the material originated from. As expected, there are significant uncertainty as to how any of these forms of protection will be enforced as ITD tries to assert itself.

The material we have drawn from our case study of ITD demonstrates, we believe, a wider range of problems associated with both appropriation and governance that firms face than are usually considered, and how stabilisation strategies help to overcome, but do not fully resolve, them. We can see how techniques of control (e.g. collaborations) and surveillance defuse potentially disruptive and destabilising conflicts over appropriation. Most importantly, the firm inscribes technologies with certain forms of IP protection which provide a legal and technical means of 'acting at a distance' on its customers.

ITD's organisational power over others can be seen as a relational capacity employed to attempt to order and maintain complex structures of socio-technical interdependence and co-ordination that limits the choice of others. Yet we have seen too that each solution creates its own new problems - such as the simplification of the database that makes it more attractive to customers yet more vulnerable to appropriation by other firms.

Discussion

Our account of ITD Design's attempts to secure and exploit its intellectual property provides, we suggest, an unusually detailed examination of the various opportunities and constraints ITD has faced in commercialising its core knowledge base. As we argued at the start of the paper, this process is always subject to uncertainties and difficulties, especially where knowledge producers and users cross the public/private divide. Moreover, institutionally, it is clear that ITD has had to cope with the problem of mixing distinct regimes of appropriation and governance. Apart from discovering how the dynamics of ordering and stabilisation operated in a specific case, what wider implications can we draw from the analysis so far?

Regimes and Ordering

First of all, at simple level, we want to argue that the commercialisation of university science is more complex than many of the debates on so-called technology transfer allow. Rather than speak of technology transfer it might be better to speak of 'technology translation' simply to draw attention to the iterative and constructed nature of building a technological innovation for various markets.
Secondly, most discussions of appropriation are limited to a consideration of the use of patents, secrecy, lead time, and support services to protect the competitive advantages of technical innovations (22). While these may all play a role, our analysis shows that the process of appropriation is more complex: protecting IP is not solely a matter of IPR, there are technical forms of protection that build protection into the technology itself. Organisations inscribe technologies with certain forms of IP protection which provide a legal and technical means of 'acting at a distance' on customers.

Indeed, in our particular case, copyright was not seen as an effective means of protection against infringement or a means of securing licensing fees. Secondary functions of IPR were considered just as or more important. These included signalling competencies to other firms and providing a (minor) bargaining chip in negotiating with larger firms.

Thirdly, and more importantly, our analysis raises wider theoretical issues associated with changes in the knowledge and innovation system itself. A commonly accepted view today is that we are witnessing the co-evolution of knowledge and institutional structures (23). The argument runs that institutional structures and divisions (for example between industry, government and university) are breaking down as large, interdisciplinary, multi-sourced and funded research groups explore strategic science issues at national and international level, such as is witnessed by the Human Genome Project. At the same time, the new sciences, notably, biotechnology, display a collapse in the cognitive, experimental and temporal gap between basic and applied science: to undertake some key basic science, new techniques of immediately commercial value (such as gene 'tool-kits') must be developed. These two, co-evolving processes, seem too to produce a situation in which the commercialisation of the science base is structurally easier to secure. One need only point to the level of commercial activity in US or European biosciences - in terms of industry funding, licensing revenue, patents granted and so on - to confirm that indeed this appears to be the case (24).

In terms of the analytical framework that has been deployed here, can we say that this co-evolution is making for more effective ordering of the commercialisation of science and more successful appropriation of knowledge? Given our earlier argument which drew on Teece's ideas, it would appear that the growth of commercial activity in bioscience should reflect the way in which those involved in this sector have managed to build a regime of appropriation which, in Teece's language, is more 'tight' than in other sectors. One can point, of course, to the much higher recourse to patenting activity in this area as an important indicator of a more formalised IP regime through which intellectual property is secured. At the same time, we should not lose sight of the fact that biotechnology has often been ahead of the law, which has meant that patent claims may not be copper-bottomed: indeed, many firms have found it difficult to codify and thereby stabilise their specific knowledge claims, as Biogen found recently with what it thought was a secure patent covering the hepatitis B vaccine.

What we can say is that as we move from one sector to another, the 'tightness' of the regime varies in terms of both codification secured and form of IP controls required and used. This means that the strategies for ordering and stabilising will also be different: for example, other findings from our study of USOs show important differences between new materials and software firms. The former were much more likely to seek to secure strong patent protection around a new process of product which would take some years to develop while the latter, with a much shorter development time, shorter market run and a dependency on other firms as either suppliers or users, will use faster market entry and niche marketing to exploit their IP, or deploy the sort of strategies we saw in the case of ITD.

Our point, then, is that different technology sectors and basic research fields do not experience the 'co-evolution' process the same way or to the same degree. Moreover, one can argue that even within technology sectors one can find evidence that suggests that commercialisation occurs at varying paces, reflecting the different conditions firms face with regard to their capacity and power to codify and protect their IP. Any wider changes in knowledge and institutional systems are mediated in important ways at the local level. The commercialisation of different field is similarly varied, as regimes of appropriation and governance are more, or less, easy to secure. This is perhaps why, especially among more vulnerable SMEs, we see the importance of developing informal trust relationships to reduce levels of uncertainty among firms dependent on each other.

From a policy perspective, many studies have found small firms engage in a higher degree of informal links with each other than large firms. The chronic (ongoing) difficulties that the firm has in trying to
stabilise its market, its relations with the university, its IPR, all explain in part the tendency that it has to prefer to use informal links to secure its position: we might argue that the informalised trust that is constructed (but as such which is always precarious) is an informalised form of IPR, IPR by proxy, if you like. Through trust it may be possible to stabilise the market relations such that ‘simplified’ knowledge-claims maintain their commercial value. Trust stabilises problematic relations and opens boundaries so facilitating socio-economic exchange and thereby appropriation. Trust simplifies the complexity of social relations and can bring conflicting interests together. Given the forms of moral regulation and self-regulation (i.e. self-governance) which underlie all forms of linkage, we need to see the ‘publicness’ or ‘privateness’ of goods as negotiable because of, or because of the lack of, elements of trust. Informal, trust based relationships can mean IPR becomes much less important to a regime of appropriation.

USOs
From a policy perspective, the growth of USOs is in part based on the belief that the exploitation of university science is easier where the commercialisation of knowledge can be conducted through shifting that knowledge into a distinct institutional structure - the spin-off firm. However, our case study shows the problems spin-offs face. Like all firms, ITD engaged in strategies that would render its business environment predictable or manipulable, positioning itself as best it can within the hierarchical networks of “the market”. The informal and formal of linkages it has (with universities or other firms) shape these networks and structure the firm’s regimes of appropriation and governance. In attempting to commercialise their work, the individuals at ITD needed to negotiate ambiguous notions of “public” and “private”, and did so in ways recognised as problematic.

From the perspective of government policy keen to improve academic-industry relations, the growth of USOs is an important structural change in the innovation system (25) rather than a temporary or cyclical one. But the success they enjoy is rooted in the regimes of appropriation and governance to which they are subject and through which they try to build for the future. USOs can be understood to be an important feature of the ecology of academic-industry collaboration, but one which can, as all others, be examined in terms of these two regimes and the ordering and stabilisation secured.

Notes
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7. Ibid., p. 287.
21. The company name and personnel have been disguised.