The Capitalization of Knowledge

A Triple Helix of University–Industry–Government

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Abbreviations

ACRI	Association of Crown Research Institutes (New Zealand)
AIM	Alternative Investment Market (UK)
CADs	Complex Adaptive Systems
CAFC	Court of Appeals for the Federal Court (USA)
CEO	chief executive officer
CNRS	National Centre for Scientific Research (France)
CRI	Crown Research Institute (New Zealand)
DARPA	Defense Research Projects Agency (USA)
DBF	dedicated biotechnological firms
EPO	European Patent Office
ERISA	Employment Retirement Income Security Act (USA)
FDI	foreign direct investment
GDP	gross domestic product
GM	genetic modification
GMO	genetically modified organism
GNF	Genomics Institute of the Novartis Research Foundation (USA)
GPL	Generalized Public License (USA)
HEI	higher education institution
HMS	Harvard Medical School
HR	human resources
ICND	Institute of Childhood and Neglected Diseases (USA)
ICT	information and communication technology
INRIA	National Institute of Computer Science (France)
IP	intellectual property
IPO	initial public offering
IPR	intellectual property rights
JCSG	Joint Center for Structural Genomics (USA)
KIS	knowledge-intensive services
LGPL	lesser Generalized Public License (USA)
LSN	Life Sciences Network (New Zealand)
MIT	Massachusetts Institute of Technology
NACE	Nomenclature générale des Activités économiques dans les Communautés

NASDAQ	National Association of Securities Dealers Automated Quotations
NIBR	Novartis Institutes for Biomedical Research (USA)
NIH	National Institutes of Health (USA)
NSF	National Science Foundation (USA)
NUTS	Nomenclature des Unités Territoriales Statistiques
NYU	New York University
OECD	Organisation for Economic Co-operation and Development
OTC	over the counter
PD	public domain
PLACE	proprietary, local, authoritarian, commissioned, expert
PoP	professor of practice
PR	proprietary research
PRO	public research organization
R&D	research and development
RCGM	Royal Commission into Genetic Modification (New Zealand)
RDI	research, development and innovation
RIO	regional innovation organizer
RoP	researcher of practice
RSNZ	Royal Society of New Zealand
SHIPS	Strategic, founded on Hybrid and interdisciplinary communities, able to stimulate Innovative critique and should be Public and based on Scepticism
SMEs	small and medium-sized enterprises
TIP	Technology Investment Program (USA)
TTO	technology transfer officer
UCSD	University of California San Diego
UCSF	University of California San Francisco
VCE	virtual centre of excellence
WYSIWYG	what you see is what you get (IT)

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Introduction: anti-cyclic triple helix

Riccardo Viale and Henry Etzkowitz

THE TRIPLE HELIX IN ECONOMIC CYCLES

The year 2009 may have represented a turning point for research and innovation policy in Western countries, with apparently contradictory effects. Many traditional sources of financing have dried up, although some new ones have emerged, for example as a result of the US stimulus package. Manufacturing companies are cutting their R&D budgets because of the drop in demand. Universities saw their endowments fall by 25 per cent or more because of the collapse in financial markets. Harvard interrupted the construction of its new science campus, while Newcastle University speeded up its building projects in response to the economic crisis. Risk capital is becoming increasingly prudent because of the increased risk of capital loss (according to the International Monetary Fund, the ratio between bank regulatory capital and risk-weighted assets increased on average between 0.1 and 0.4 for the main OECD countries during 2009) while sovereign funds, like Norway's, took advantage of the downturn to increase their investments. According to the National Venture Capital Association, American venture capital shrank from US$7.1 billion in the first quarter of last year to US$4.3 billion in the first quarter of 2009 (*New York Times*, 13 April 2009). Many of the pension funds, endowments and foundations that invested in venture capital firms have signalled that they are cutting back on the assets class. The slowdown is attributable in part to venture capitalists and their investors taking a wait-and-see approach until the economy improves.

The future outlook for R&D looks poor unless a 'white knight' comes to its rescue. This help may come from an actor whose role was downplayed in recent years, but that now, particularly in the USA, seems to be in the ascendant again. It is the national and regional government that will have to play the role of the white knight to save the R&D system in Western economies (Etzkowitz and Ranga, 2009). In the previous 20 years the proportion of public financing had gradually fallen in percentage terms, while the private sector had become largely dominant (the percentage of Gross Domestic Expenditure in R&D financed by industry now exceeds 64 per cent in OECD countries). In some technological sectors, such as biotechnology, the interaction between academy and industry has become increasingly autonomous from public intervention. University and corporate labs established their own agreements, created their own joint projects and laboratories, exchanged human resources and promoted the birth of spin-off and spin-in companies without relevant help from local and national bodies. Cambridge University biotech initiatives or University of California at San Diego relations with biotech companies are just some of many examples of double-helix models of innovation. In other countries and in other technological sectors the double-helix model didn't work and needed the support of the public helix. Some European countries, like France, Germany and Italy, saw a positive intervention of public institutions. In France, Sophia Antipolis was set up with national and regional public support. In Italy, support from Piedmont regional government to the Politecnico of Turin allowed the development of an incubator of spin-off companies that incubated more than 100 companies.

In sectors such as green technologies, aerospace, security and energy, public intervention to support the academy–industry relationship is unavoidable. Silicon Valley venture capitalists invested heavily in renewable energy technology in the upturn, and then looked to government to provide funding to their firms and rescue their investments once the downturn took hold. In emerging and Third World economies, the role of the public helix in supporting innovation is also unavoidable. In the least developed countries industry is weak, universities are primarily teaching institutions and government is heavily dependent upon international donors to carry out projects. In newly developed countries the universities are developing research and entrepreneurship activities and industry is taking steps to promote research, often in collaboration with the universities, while government plays a creative role in developing a venture capital industry and in offering incentives to industry to support research through tax breaks and grants.

The novelty of the current crisis is that the public helix becomes crucial even in countries and in sectors where the visible public role was minimal in the past. The Advanced Technology Program, the US answer to the European Framework Programmes, shrunk to virtual inactivity with zero appropriations under the Bush Administration but has found a second life under the Obama Administration and has been renamed the TIP (the Technology Investment Program).

The triple-helix model seems to play an anti-cyclic role in innovation.

It is a default model that guarantees optimal or quasi-optimal levels of academy–industry interaction through public intervention. It expresses its potential when the interaction is not autonomous, as is now the case in times of crisis, and the collaboration between universities and companies calls for financial support and organizational management. It works as a 'nudge tool' (Thaler and Sunstein, 2008), whose aim is to maintain a sufficient flow of innovation through the right incentives and institutional mechanisms for academy–industry collaboration.

In this book we will examine various models for the capitalization of knowledge and attempt to discern the features of the new relationship that is emerging between the state, universities and industry. Are they converging in a certain way across different sociopolitical cultures and political institutions?

Which of the key groups (scientists, politicians, civil servants, agency officials, industrialists, lobby groups, social movements and organized publics) are emerging as relevant players in the science and technology (S&T) policy arenas? What and how divergent are the strategies that they are pursuing and at what levels in the policy-making process do they take part?

What are the 'appropriate' policies that respond to these changes? Do they call for a radical paradigm-like shift from previously established research policy?

What degrees of freedom and autonomy can universities gain within the new triangular dynamics? Are the new patterns of interaction among those sectors designing a new mode of knowledge production? How are such changes altering the structure and operations of the knowledge-producing organizations inside these sectors?

POLYVALENT KNOWLEDGE: THREATS AND BENEFITS TO ACADEMIC LIFE

The triple helix is a model for capitalizing knowledge in order to pursue innovation (Etzkowitz, 2008). Academic communities are fearful that capitalization will diminish the university goal of knowledge production *per se*. This fear seems to be linked to a traditional image of the division of labour in universities. Curiosity-driven research is separated from technology-driven research. Therefore, if a university focuses on the latter, it handicaps and weakens the former. On the contrary, in our opinion, in many technological fields knowledge production simultaneously encompasses various aspects of research. The theory of polyvalent knowledge (Etzkowitz and Viale, 2009) implies that, contrary to the division of knowledge into divergent spheres – applied, fundamental, technological – or into mode 1 (disciplinary knowledge) and mode 2 (applied knowledge) (Stokes, 1997; Gibbons et al., 1994), a unified approach to knowledge is gradually becoming established. In frontier areas such as nanotechnologies and life sciences, in particular, practical knowledge is often generated in the context of theorizing and fundamental research. And, on the other hand, new scientific questions, ideas and insights often come from the industrial development of a patent and the interaction of basic researchers and industrial labs. The polyvalence of knowledge encourages the multiple roles of academics and their involvement in technology firms, and vice versa for industrial researchers in academic labs.

One way of testing the reliability of this theory is to verify whether or not there is any complementarity between scientific and technological activities, measured by the number of publications and patents respectively. In the case of polyvalent knowledge, the same type of knowledge is able to generate both scientific output and technological output. Since the scientific knowledge contained in a publication generates technological applications represented by patents, and technological exploitation generates scientific questions and answers, we should expect to see some complementarity between publishing and patenting. Researchers who take out patents should show greater scientific output and a great capacity to affect the scientific community, measured by the impact factor or citation index.

In other words, increasing integration between basic science and technology implies that there is no rivalry between scientific and technological output. The rivalry hypothesis holds that there is a crowding-out effect between publication activities and patenting. The substitution phenomenon between publications and patents stems from the inclusion of market-related incentives into the reward structure of scientists (Dasgupta and David, 1985; Stephan and Levin, 1996). Scientists increasingly choose to allocate their time to consulting activities and research agreements with industrial partners. They spend time locating licensees for their patents or working with the licensee to transfer the technology. Time spent doing research may be compromised. These market goals substitute peer-review judgement and favour short-term research trajectories and lower-quality research (David, 1998). Moreover, the lure of economic rewards encourages scientists to seek IP (intellectual property) protection for their research results. They may postpone or neglect publication and therefore public disclosure. Industry funding, commercial goals and contract requirements may lead researchers to increase secrecy with regard to research methodology and results (Blumenthal et al., 1986; Campbell et al., 2002). Both these mechanisms may reduce the quantity and the quality of scientific production. This behaviour supports the thesis of a trade-off between scientific research and industrial applications.

On the contrary, a non-rivalry hypothesis between publishing and patenting is based on complementarity between the two activities. The decision of whether or not to patent is made at the end of research and not before the selection of scientific problems (Agrawal and Henderson, 2002). Moreover, relations with the licensee and the difficulties arising from the development of patent innovation can generate new ideas and suggestions that point to new research questions (Mansfield, 1995). In a study, 65 per cent of researchers reported that interaction with industry had positive effects on their research. A scientist said: 'There is no doubt that working with industry scientists has made me a better researcher. They help me to refine my experiments and sometimes have a different perspective on a problem that sparks my own ideas' (Siegel et al., 1999).

On the other hand, the opposition between basic and technological research seems to have been overcome in many fields. In particular, in the area of key technologies such as nanotechnology, biotechnology, ICT (information and communication technologies), new materials and cognitive technologies, there is continuous interaction between curiosity-driven activities and control of the technological consequences of the research results. This is also borne out by the epistemological debate. The Baconian ideal of a science that has its *raison d'être* in practical application is becoming popular once again after years of oblivion. And the technological application of a scientific hypothesis, for example regarding a causal link between two classes of phenomena, represents an empirical verification. An attempt at technological application can reveal anomalies and incongruities that make it possible to define initial conditions and supplementary hypotheses more clearly.

In short, the technological 'check' of a hypothesis acts as a 'positive heuristic' (Lakatos, 1970) to develop a 'positive research programme' and extend the empirical field of the hypothesis. These epistemological reasons are sustained by other social and economic reasons. In many universities, scientists wish to increase the visibility and weight of their scientific work by patenting. Collaboration with business and licensing revenues can bring additional funds for new researchers and new equipment, as well as meeting general research expenses. This in turn makes it possible to carry out new experiments and to produce new publications. In fact Jensen and Thursby (2003) suggest that a changing reward structure may not alter the research agenda of faculty specializing in basic research. Indeed, the theory of polyvalent knowledge suggests that dual goals may enhance the basic research agenda.

COMPLEMENTARITY BETWEEN PUBLISHING AND PATENTING

The presence of a complementary effect or the substitution of publishing and patenting has been studied empirically in recent years. Agrawal and Henderson (2002) have explored whether at the Departments of Mechanical and Electrical Engineering of MIT patenting acts as a substitute or a complement to the process of fundamental research. Their results suggest that while patent counts are not a good predictor of publication counts, they are a reasonable predictor of the 'importance' of a professor's publications as measured by citations. Professors who patent more write papers that are more highly cited, and thus patenting volume may be correlated with research impact. These results offer some evidence that, at least at the two departments of MIT, patenting is not substituting for more fundamental research, and it might even be an accelerating activity.

Stephan et al. (2007) used the Survey of Doctorate Recipients to examine the question of who is patenting in US universities. They found patents to be positively and significantly correlated to the number of publications. When they broke the analysis down into specific fields, they found that the patent–publishing results persisted in the life sciences and in the physical/engineering sciences. The complementarity between publishing and patenting in life sciences has been studied by Azoulay et al. (2005). They examined the individual, contextual and institutional determinants of academic patenting in a panel data set of 3884 academic life scientists. Patenting is often accompanied by a flurry of publication activity in the year preceding the patent application. A flurry of scientific output occurs when a scientist unearths a productive domain of research. If patenting is a by-product of a surge of productivity, it is reasonable to conclude that a patent is often an opportunistic response to the discovery of a promising area.

In the past, senior scientists and scientists with the most stellar academic credentials were usually also the most likely to be involved in commercial endeavours. But a feature of the Second Academic Revolution and the birth and diffusion of entrepreneurial universities is that the academic system is evolving in a way that accommodates deviations from traditional scientific norms of openness and communalism (Etzkowitz, 2000). In fact, Azoulay et al.'s (2005) data indicate that many patenting events now take place in the early years of scientists' careers and the slope of the patent experience curve has become steeper with more recent cohorts of scientists. Patents are becoming legitimate forms of research output in promotion decisions. Azoulay et al. (2005) show that patents and papers encode similar pieces of knowledge and correspond to two types of output

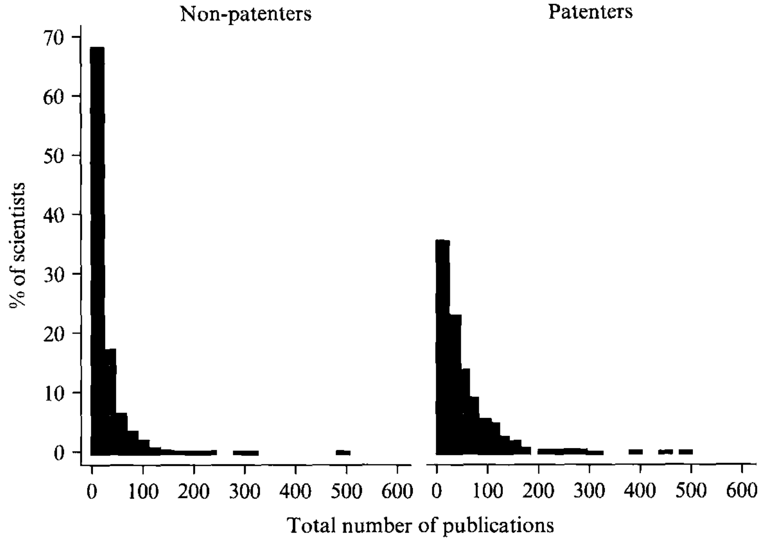

Figure I.1 *Distribution of publication count for patenting and non-patenting scientists*

that have more in common than previously believed. Figure I.1 shows the complementary of patenting and publishing in Azoulay et al. (2005). It plots the histogram for the distribution of publication counts for our 3884 scientists over the complete sample period, separately for patenting and non-patenting scientists.

The study that makes the most extensive analysis of the complementarity between patenting and publishing is by Fabrizio and DiMinin (2008). It uses a broad sample drawn from the population of university inventors across all fields and universities in the USA, with a data set covering 21 years. Table I.1 provides the annual and total summary statistics for the entire sample and by inventor status. A difference of mean test for the number of publications per year for inventors and non-inventors suggests that those researchers holding a patent applied for between 1975 and 1995 generate significantly more publications per year than non-inventors. The inventors in their sample are more prolific in terms of annual publications, on the order of 20–50 per cent more publications than their non-inventor colleagues. The results suggest also that there is not a significant positive relationship between patenting and citations and a faculty member's publications.

Nor was evidence of a negative trade-off between publishing and patenting found in Europe. Van Looy et al. (2004) compared the publishing

Table I.1 Patenting and publishing summary statistics for inventors and non-inventors

	Inventors		**Non-inventors**		**All**	
	Mean	St. dev.	Mean	St. dev.	Mean	St. dev.
Annual pubs	3.99	5.18	2.24	2.96	3.12	4.32
Annual pats	0.56	1.55	0	0	0.28	1.14
Total pubs	79.93	84.78	43.71	47.72	62.00	71.30
Total pats	11.02	16.21	0	0	5.57	12.77

output of a sample of researchers in the contract research unit at the Catholic University of Leuven in Belgium with a control sample from the same university. The researchers involved in contract research published more than their colleagues in the control sample. Univalent single-sourced formats are less productive than the polyvalent research groups at the Catholic University of Louvain that 'have developed a record of applied publications without affecting their basic research publications and, rather than differentiating between applied and basic research publications, it is the combination of basic *and* applied publications of a specific academic group that consolidates the groups R&D potential' (Ranga et al., 2003, pp. 301–20). This highly integrated format of knowledge production evolved from two divergent sources: industrial knowledge gained from production experience and scientific knowledge derived from theory and experimentation.

In Italy an empirical analysis of the consequences of academic patenting on scientific publishing has been made by Calderini and Franzoni (2004), in a panel of 1323 researchers working in the fields of engineering chemistry and nanotechnologies for new materials over 30 years. As shown in Table I.2, the impact of patents is positive in the quantity of publications. Development activities are likely to generate additional results that are suitable for subsequent publications, although there might be one or two years of lag. Moreover, quality of research measured by the impact factor is likely to increase with the number of patents filed in the period following the publication. Scientific performance increases in the proximity of a patent event. This phenomenon can be explained in two ways. Top-quality scientific output generates knowledge that can be exploited technologically. And technological exploitation is likely to generate questions and problems that produce further insights and, consequently, additional publications. The same kind of results are found by Breschi et al. (2007), in a study done on a sample of 592 Italian academic inventors (see Table I.3).