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Knowledge Transfer from Public Research Organisations

Science and Technology Options Assessment

STOA

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AUTHORS

Erik Arnold
Paula Knee
Neil Brown
Zsuzsa Jávorka
Flora Giarracca
Sabeen Sidiqui

RESPONSIBLE ADMINISTRATORS

Miklós Györffi and Theodoros Karapiperis
Science and Technology Options Assessment
Directorate G: Impact Assessment and European Added Value
DG Internal Policies
European Parliament
Rue Wiertz 60 - RMD 00J008
B-1047 Brussels
E-mail: theodoros.karapiperis@ep.europa.eu

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ABOUT THE EDITOR

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stoa@ep.europa.eu

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Knowledge Transfer from Public Research Organisations

Final Report

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Abstract

This study describes knowledge transfer from European universities and institutes to industry, focusing on the role of the Industrial Liaison / Technology / Knowledge Transfer Office function. It explores practices in European institutions and compares these with international ones, especially from the USA. The project is based upon a comprehensive literature review and a programme of detailed case studies of knowledge transfer strategies and practices. It addresses the wide range of knowledge transfer activities undertaken by public research organisations, in addition to IP exploitation and their different effects on innovation in the business sector. It presents a model of the transition of PROs' knowledge transfer strategies from pure technology transfer based only on IP to a broader role in knowledge transfer and ultimately to a two-way process of knowledge exchange between PROs and industry and wider society. The report presents a number of policy options to support this process.

Table of Contents

Table of Figures

Summary

Knowledge transfer, or more accurately knowledge *exchange*, between Public Research Organisations (PROs) is not, and should not be, an activity solely focused on the exploitation of PRO-owned patents

1. PROs have a wider role in innovation systems than simply providing new technologies to individual businesses. They provide access to skilled personnel, assist businesses with short-term problem-solving, support the development of research and innovation capabilities through collaborative working and provide access to new ideas and concepts. In this sense they are engaging in *knowledge* and not solely *technology transfer.*

1. In this wider role, a range of different knowledge transfer mechanisms are used to transfer and exchange knowledge between PROs and industry including publications, consultancy, contract and collaborative R&D and informal interactions as well as exploiting formal intellectual property generated by PRO research. Studies demonstrate that businesses make use of, and value, all such mechanisms. Individual companies tend to make use of several mechanisms with the pattern of use dependent upon the type of knowledge they wish to access, the focus of their particular innovation activities and their industrial sector.

2. This wider concept of knowledge exchange is in alignment with the public good role of PROs in society, where that they play an active role in diffusing knowledge to where it can be put to best use. This is not to suggest that the protection and exploitation of formal IP, in the form of patents, has no role to play; in some industrial sectors (such as pharmaceuticals, electronics and telecommunications) patents are essential to innovation, but for many sectors and individual businesses the role of patents is much less important. Furthermore, even where exploiting PRO patents is important, businesses tend to interact with PROs in multiple ways to access the codified and tacit knowledge needed for technology commercialisation. In fact many cases PRO patents are licensed to businesses with which a longer-term and relationship has already been established.

3. As a result, maximising income to PROs from IP should not be the focus of knowledge exchange activities. Firstly, this is in opposition to the public good role of PROs, and therefore IP exploitation via patents should only be undertaken where this is essential to allow businesses to undertake further development and commercialisation activities. Secondly, very few KTOs are able to generate a surplus from their IP activities. The experience of the last 20 years, in the USA and Europe, has demonstrated that the majority of the IP income is generated by a very small number of internationally renowned research intensive PROs.

4. Therefore the over-arching aim of knowledge exchange is proactive knowledge diffusion and public policy needs to enable and support PROs in this role.

PROs in Europe are on a journey towards establishing a fully embedded culture of knowledge exchange

This journey consists of three phases:

5. **Stage 1: Establishing framework conditions** – the creation of formal policy support for *knowledge exchange* and not *technology transfer*. This typically occurs at national and/or regional level. At a policy-making level this requires the removal of legal and regulatory barriers to knowledge exchange (where they exist) and the establishment of a strong policy position with respect to knowledge exchange between PROs and industry.

6. **Stage 2: Policy implementation** – the development and implementation of knowledge exchange strategies, institutional policies, processes and governance structures at individual PROs. This includes, but is not limited to, the creation of a professional support office and the recruitment of professional knowledge exchange staff.

7. **Stage 3: Embedding knowledge exchange mission** – consolidating the knowledge exchange mission and embedding a knowledge exchange culture across the PRO, with appropriate incentives and rewards for PRO staff to deliver on all three institutional missions that is: teaching; research and knowledge exchange.

8. Currently European and individual PROs are at different places on the journey and therefore are many opportunities for later adopters to access good practice and learn from more experienced PROs and policy-makers.

Policy options

A. Commission Communication on Knowledge Exchange

The Commission and Council policy recommendations on knowledge transfer[1] were published 4-5 years ago and it is timely, in light of the policy developments of Innovation Union and Horizon2020, and the degree of variability of practice across Member States to increase awareness of, and place much greater emphasis on, the importance of *knowledge exchange* rather than *technology transfer* and to update and improve policy recommendations.

B. Greater Use of Structural Funds to Support the Development of Capacities for Knowledge Exchange

While structural funds already have a focus on innovation, DG Regio could be encouraged to place a much greater emphasis on the development of *knowledge exchange* capabilities and capacities within regional PROs and to ensure that regional innovation strategies avoid the technology transfer paradigm. This support should also ensure that policy-makers and PROs in lagging countries are able to maximise opportunities to learn from experienced countries.

C. Support for Sharing Good Practice

Early adopters have gained considerable experience in knowledge exchange and while there is no one-size-fits-all approach to knowledge exchange strategies and operations, there is a wealth of good practice across Europe. This needs to be identified and made more widely available, particularly to the lagging countries to enable them to climb the learning curve faster:

9. Public financial support for the identification, collection and pro-active dissemination of good practice widely across the EU with a particular focus on improving lagging countries.

10. Widening the provision of professional networks in knowledge exchange to meet the needs of different types of PRO, from the research intensive to the more regional less research-intensive institutions. This might be achieved through providing public financial support for extending the reach of existing networking organisations or supporting the creation of new organisations to meet the specific needs of different types of PROs.

11. Public financial support to individual PROs in the process of establishing knowledge exchange missions to access good practice 'hands-on' through visiting established professional knowledge exchange offices, developing relationships with more experienced players and acquiring professional mentors.

[1] COM (2007) 182 final & COM(2008) 1329

D. Pan-European Knowledge Exchange

Maximising learning for pan-European knowledge exchange from the Framework Programme and Knowledge and Innovation Communities (KICs) of the EIT.

12. A study to identify and disseminate best practice in pan-European knowledge exchange with a particular focus on the Framework Programmes – to identify, for example, good practice in contracts and collaboration agreements to act as exemplars for future partnerships.

13. The KICs have been fully operational for a relatively short period of time and therefore information on their practical experience in pan-European knowledge exchange is only just becoming available. It is timely for the Commission to implement a process to regularly monitor and review the knowledge exchange strategies and processes of the KICs in order to: ensure they have appropriate strategies and processes, to identify good practice, and identify an unforeseen implications for the participating organisations.

E. Incorporate Advice on Changing Academic Career Structures in Commission Communications on Higher Education

14. The Commission as a catalytic actor in the higher education arena is able to influence HEIs (in particular) and therefore future Commission Communications on higher education should include recommendations on need for academic reward and recognition systems to encompass the *three institutional missions* – education, research and knowledge exchange. The European Charter for Researchers could also be amended accordingly. Furthermore the Commission could fund activities to identify and disseminate good practice in academic career structures at both institutional and national levels.

15. Similarly processes to assess and assure PRO quality should encompass the three missions. This could then be used not only to accredit institutions but also to inform funding allocations as part of a process that balances core, competitive and performance-based funding allocations.

F. Coordinate and Promote the Development of Professional Career Structures for KTO Staff

A number of processes are underway to develop and accredit a career structure for KTO staff and provide accredited continuing professional development at both national level (e.g. IKT in the UK), European (ASTP, ProTon, EuKTS) and international level (Alliance of Technology Transfer Professionals, ATTP). EuKTS, an OMC Net activity under Framework 7, is developing an accreditation system for knowledge exchange it comes to an end in March 2012 and the Commission needs to ensure that its outputs are promoted and disseminated widely.

G. Monitor and Measure Knowledge Exchange at a European Level

Measurement of knowledge exchange is currently too heavily focused on metrics that assess the exploitation of IP and furthermore very few data are collected at a European level. Collecting statistics not only facilitates monitoring and analysis but also establishes a subject as important and so drives behaviour. The Commission could initiate a regular survey of PROs to collect data on knowledge exchange activities and outputs. This would build on the experience developed in a number of early adopter countries in terms of a broader set of metrics and in implementing regular surveys to collect them. It should aim to reach a significant proportion of the broad range of European PROs across all Members States.

H. Monitor and Review Industrial Participation in Horizon 2020

The Parliament needs to monitor and review participation in order to ensure that all possible measures are being taken to increase industrial participation in Horizon 2020.

I. Open Access to Horizon 2020 Research Outputs

Publication remains an extremely important knowledge exchange mechanism for industry to access PRO generated knowledge. However academic publications remain beyond the reach of many businesses behind the firewalls of academic publishers. For publicly funded research outputs there is a strong argument that this should not be the case and that an open access approach to publication is more appropriate. The concept of Open Access is featured in the current proposed Regulation of the European Parliament and of the Council 'laying down the rules for the participation and dissemination in 'Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020)' [2] and it should be endorsed by the Parliament.

[2] COM(2011) 810 final 2011/0399 (COD), November 2011

Report Highlights – Key Findings

The taxpayer funds Public Research Organisations (PROs), that is universities and research institutes, as an investment in the production of knowledge on behalf of society. This report, commissioned by STOA, focuses on the **role of PRO Knowledge Transfer Offices in knowledge transfer and exchange between researchers and potential users of knowledge in pursuit of technological and economic impact.** The study is focused in particular on knowledge transfer to industry.

Innovation and the role of PROs

16. Innovation models have developed over the last few decades from relatively simple linear innovation models that regard PROs as providers of new technologies to businesses who go to commercialise them, to more complex *innovation systems* of networked innovation actors in the private and public sectors supported by a range of institutional frameworks and infrastructures such as financial environments, IP structures and culture.

17. Businesses are the main actors in innovation; with innovation a process of continuous interaction and feedbacks between perceptions of market opportunities, technological capabilities, and learning processes.

18. Within the innovation system, businesses make use of a wide range of inputs to innovation; both from internal sources - that are much wider than just in-house R&D, and from external sources – most typically from their suppliers and also from customers. PROs are just one source among many external inputs to firms' innovation processes and, in general, they are used to a much lesser extent than other sources.

19. Different sectors innovate in different ways and some sectors are more predisposed to work with PROs than others

1. Businesses in science-based sectors such as pharmaceuticals, electronics, chemicals and materials, rely on fundamental developments in basic science and as a result have the closest ties with PROs. These sectors also tend to make use of formal intellectual property to protect their innovations.

2. Other sectors rely to a greater extent on their suppliers and customers for their innovation inputs and make use of a range of mechanisms for protection such as copyright, trademarks, secrecy, internal know-how and technological leadership as well as leadership in professional skills such as design, marketing and advertising.

Knowledge transfer mechanisms

3. In an innovation system PROs have a wider role than simply providing new technologies and ideas to businesses - assisting with short-term problem-solving as well as supporting the development of research and innovation skills and capabilities through transferring complex codified and tacit new knowledge to businesses.

4. A range of different knowledge transfer mechanisms are used to transfer knowledge from PROs to industry including publications, consultancy, contract and collaborative R&D, informal interactions and exploiting PRO generated IP. Industry makes use of and values all mechanisms to differing degrees. Individual companies tend to make use of several mechanisms depending on the type of knowledge they wish to access and focus of their innovation activities.

5. Different knowledge transfer mechanisms transfer different types of knowledge – with publications and patents transferring codified (written) knowledge and more interactive mechanisms, such as contract and collaborative R&D, transferring both codified and tacit knowledge (know-how, skills).

6. Industry ranks knowledge transfer in order of importance as follows

7. The traditional published academic outputs such as journal articles, conference proceedings and books
8. Informal interactions including interactions at conferences, seminars and via professional associations as well as personal contacts and relationships
9. More in depth research relationships – including contract research, consultancy, collaborative R&D and accessing research skills (through funding PhDs etc.)
10. Exploiting PRO IP through licensing patents, copyright etc.

11. Exploiting IP through formal transactions alone is generally considered to be of lesser importance by industry. It is relatively more important to the science-based sectors such as pharmaceuticals, electronics, chemicals and materials. Nevertheless, these sectors also make wide use of other knowledge transfer mechanisms to improve their knowledge base and develop long-term relationships with relevant academics and departments.

12. Codified knowledge alone is generally insufficient for commercialising IP. The patented technology is usually very early stage and further input from researchers is required to support its commercial development. As a result, licence agreements are typically supported by other knowledge transfer mechanisms such as consultancy, contract and collaborative R&D to access the skills and tacit knowledge required to fully understand and develop the technology.

13. In general, the different knowledge transfer mechanisms are complementary rather than substitutes.

14. IP exploitation leads predominantly to benefits in individual businesses. The more collaborative methods result in wider benefits to society, not only increasing the potential for knowledge creation and spillovers, but also developing the longer-term relationships essential to a well-functioning innovation system.

Knowledge transfer offices

15. Across Europe, innovation policy emphasises the role of PROs, assigning them a 'third mission' to support innovation in addition to their core missions of education and research.

16. Early innovation policy, based on the linear model, saw PROs primarily as providers of research outputs in the form of IP. This led to the development of Technology Transfer Offices with the role of protecting, licensing and commercialising PRO-generated IP. The development of the systems models of innovation and the practical experience of PROs has led to a broader understanding of the role of PROs and the development of Knowledge Transfer Offices (KTOs) to support *knowledge* rather than simply *technology* transfer.

17. The role of KTOs in the innovation systems is to reduce the transaction costs of transferring uncertain and often un-codifiable knowledge from PROs to industry by
18. Bridging the cultural barriers between PRO researchers and industry
19. Professionalising the interactions and relationships
20. Helping PROs to become essential components of an inter-connected innovation system.

21. As a result very few PROs have KTOs that focus solely on IP exploitation. The role of KTOs is, instead, to maximise the volume and impact of KT activities carried by academic staff through the professionalisation of the industrial interface and the widening of academic participation in knowledge transfer activities.

22. Most European PROs have institutional strategies that explicitly include a knowledge transfer mission, with a member of the PRO leadership team, usually the vice-rector (or equivalent) for research, allocated responsibility for knowledge transfer and an expectation that academic staff will increasingly engage in knowledge transfer activities.

23. KTOs are structured in a number of ways, but a model that ensures a common mission for the KTO and academics while enabling a degree of autonomy to act is essential. Physical and intellectual proximity to researchers is more important that the actual organisational structure.

24. It is important that KTOs do not become a barrier to knowledge transfer. This can occur if, for example, they take an overly protective position on IP.

25. A knowledge transfer profession has been developing over the last 10-15 years, with KTOs increasingly staffed by knowledge transfer professionals. These are typically people with research backgrounds (often a PhD) and relevant business experience and/or specific professional experience in areas such as intellectual property, finance and marketing and communications

26. In terms of income very few KTOs generate a surplus from their IP activities. Early adopters of innovation/technology transfer policy saw IP commercialisation as a source of revenue for PROs, and therefore a route to creating self-funded KTOs, but this has not come to pass. Other KT mechanisms, such as consultancy and contract/collaborative R&D, while generating important income from the PRO do not generate revenue directly to fund the KTOs.

Creating an embedded culture of knowledge transfer/exchange takes time

27. The development of a third mission for PROs takes time and countries and individual PROs are on a journey, with each country and PRO at different stages. The aim is to create a functioning innovation system that contains pro-active and well-connected PROs with appropriate and effective knowledge exchange strategies and processes (including KTOs). Achieving this requires significant cultural as well as strategic and operational changes within PROs.

28. This journey consists of three phases:

29. **Stage 1: Establishing framework conditions** – the creation of formal policy support for *knowledge* (and not *technology*) transfer. This typically occurs at national and/or regional level. At a policy-making level this requires the removal of legal and regulatory barriers to knowledge transfer (where they exist) and the establishment of a strong policy position with respect to knowledge transfer and exchange between PROs and industry (and other potential users of PRO-generated knowledge).

30. **Stage 2: Policy implementation** – the development and implementation of knowledge transfer strategies, institutional policies, processes and governance structures at PROs – all of which should be closely aligned with the research mission. This includes the creation of a Knowledge Transfer Office (KTO) and the recruitment of professional knowledge transfer staff. Strategies and activities will acknowledge that academic staff are at the heart of knowledge transfer and put processes in place, such as training and awareness raising, to encourage and enable their participation in knowledge transfer.

31. **Stage 3: Embedding knowledge exchange mission** – consolidating the knowledge exchange mission and embedding a knowledge exchange culture across the PRO and developing an outward-looking and entrepreneurial culture throughout the PRO, with appropriate incentives and rewards for academics and KTO staff and, over time, embedding the PRO within appropriate professional, sector and disciplinary networks.

32. The majority of European countries have reached phase 1 but their individual PROs are in various stages of development in phase 2. No European PROs can be considered to have fully reached phase 3 but a number of PROs in the early-adopting countries are getting close to that point. Achieving a fully embedded knowledge transfer mission will take considerable time – behavioural and cultural change is a notoriously slow process and there is still resistance to change among the academic community. Even amongst the early-adopters of knowledge transfer there is still a long way to go before the third mission is a truly embedded feature of PROs.

Barriers to fully embedding a culture of knowledge exchange remain

Even for those countries that have made significant progress in knowledge transfer, to achieve a fully embedded knowledge exchange mission in PROs a number of remaining challenges need to be overcome:

33. **An over-focus on technology (IP-based) transfer can hinder knowledge transfer between PROs** and businesses. The *knowledge transfer,* as opposed to solely technology transfer role of PROs is not fully recognised in all relevant policy. IP exploitation needs to be acknowledged as just one element in knowledge transfer – more suitable for some PROs and some sectors than others. Policies that regard income from IP as a key output of knowledge transfer tend to lead to KTO incentive structures that present additional barriers to the flow and exchange of knowledge and the building of relationships between PROs and industry.

34. **A lack of well-defined metrics for knowledge transfer.** Linked to the point above is the fact that metrics to assess KTO performance and impact remain focused on technology transfer outputs – numbers of invention disclosures, patents filed and approved, licence agreements and licence income, etc. This is due, in part, to the initial focus on technology transfer but also the convenience of measuring outputs that are easily identifiable and countable. Better metrics are being implemented in some countries and the good practice could be shared.

35. **Lack of the culture of knowledge transfer within the academic community.** A key issue in developing a truly embedded knowledge exchange culture is the structure of career development paths for academics. In the majority of PROs recognition and reward systems for academics remain based on the two traditional missions of education and research, resulting in no incentives, in career terms, to engage in knowledge transfer. This means that, at present, only those academics personally motivated to work with businesses do so. Again, a small number of PROs are starting to address this.

36. **Recruiting and retaining professional knowledge transfer staff.** Despite the development and growth of a knowledge transfer profession, PROs still experience difficulties recruiting and retaining KTO staff. While in many countries the pool of KT professionals is still relatively small, the more significant issue is the ability to reward staff appropriately. It is common practice in several European countries for KTO staff to be regarded as part of the PRO's administrative structure. This can place restrictions on a PRO's ability to pay appropriate salaries to attract and retain high quality staff with both academic and business experience.

37. **Cross-border knowledge transfer.** Differences in knowledge transfer strategies and policies at national and PRO level can impede contract negotiations for cross-border knowledge transfer, particularly where several PROs are working together with businesses in joint R&D activities. IP arrangements are often a cause of contention in R&D contract negotiations, slowing down the process and delaying the start of research activities.

38. **Best practice is not shared as widely as it could be.** Considerable experience has been gained in the early-adopting countries and PROs but this is not being shared as widely as it could be to enable later adopters to benefit. As the countries and their PROs implement knowledge transfer and exchange policies and as they move from phase 1 to phase 2 (and later to phase 3) opportunities for them to learn from earlier experience would enable them to avoid pitfalls and climb the learning curve much more quickly. Accessing good practice will enable them to reach an embedded third mission as quickly and effectively as possible.

1. Introduction

The taxpayer funds Public Research Organisations (PROs), that is universities and research institutes, as an investment in the production of knowledge on behalf of society. This report, commissioned by STOA, focuses on the **role of PRO Knowledge Transfer Offices in knowledge transfer and exchange between researchers and potential users of knowledge in pursuit of technological and economic impact.** The study is focused in particular on knowledge transfer to industry.

The role of universities has evolved and expanded throughout their existence, from the scholarly pursuits of the medieval universities, the education of professionals in the 19th century and a much increased research role in the 20th century. In the broadest sense the role of universities is to produce knowledge and to make it available to society. Throughout 20th century universities have been responsible for two core missions: providing higher-level education and conducting research, and making the knowledge generated available to society through their graduates and the traditional published outputs of scholarship and research. In more recent times there has been a move towards a more pro-active interaction between universities and society to assist the transfer of knowledge from universities to society. The addition of this so-called 'third mission' has been driven largely by innovation policy at the national, regional and European level and, as a result, has focused in particular on the industrial exploitation of the outputs from science and engineering research in pursuit of economic growth.

Innovation policy has also been directed at public research institutes and laboratories, which are also expected to engage more actively with society through putting in place structures and processes to transfer their research-generated knowledge to industry, primarily, but also to other users.

This report is structured as follows:

2. Chapter 2 describes the methodology of the study.
3. Chapter 3 presents a review of the innovation studies literature to describe how innovation occurs and the differences in innovation processes in different sectors. Theses differences are important to understanding the extent to which different sectors interact with PROs and the methods they use to interact.
4. Chapter 4 addresses the role of PROs in innovation. It describes the different mechanisms by which PROs engage with industry to transfer and exchange knowledge and the relative importance to industry of different knowledge transfer mechanisms – both in general and for different sectors.
5. Chapter 5 looks at the role of Knowledge Transfer Offices (KTOs) within PROs more specifically - in terms of both economic theory and the actual practice of knowledge transfer in European and USA KTOs.
6. Chapter 6 provides an analysis of the findings, presenting a descriptive model of a three-stage process to develop knowledge transfer or 'third' missions in PROs. It also describes the key barriers to achieving effective knowledge transfer missions in PROs.
7. Chapter 7 presents the summary and conclusions of the study.
8. Chapter 8 presents policy options to overcome the barriers to knowledge transfer from PROs and ensure the widest uptake of a third mission across European PROs.

A note on the text: Throughout the report we mostly use the term 'Knowledge Transfer Office' or 'KTO' to denote the office within a PRO that is responsible for both technology transfer (based on the exploitation of formal intellectual property) as well as wider forms of knowledge transfer (as described in Chapter 4). When it is more appropriate to do so, we use the more specific term 'Technology Transfer Office' or 'TTO'. This is usually the case when referring to such offices in the USA where typically they only focus on technology transfer or when referring to some of the older European PROs, whose early offices were also only focused on technology transfer.

9. Methodology

The study was conducted in two phases. In phase 1 a literature review of the published and grey literature on technology transfer from PROs and an analysis of the patterns of patenting in European PROs were conducted. The literature review identified that the role of PROs in innovation is much broader than the concept of *technology transfer* – where technology transfer is defined as the exploitation of formal intellectual property generated by PROs from their research activities. Therefore to better understand the full extent of the role of PROs in the innovation it was necessary to broaden the remit of the study to encompass the transfer of *knowledge* in the broadest sense rather than focus only on the transfer of formal intellectual property.

Phase 1 generated a series of research questions to investigate this wider role of PROs in *knowledge transfer and exchange*. These were addressed through the development of detailed case studies of the knowledge transfer practices of 22 PROs, 19 in Europe and three in the USA, plus additional desk research and literature reviews. The research questions and case study sample of PROs are provided in Appendix A.

10. How Innovation Occurs

1. Models of Innovation

New knowledge plays an important role in innovation and therefore understanding how new knowledge flows in the economy and how to make best use of knowledge is important to the development of appropriate innovation policies.

Early innovation policy was grounded in the conceptualisation of innovation as a **linear process** whereby scientific knowledge generated from basic research, typically conducted within PROs (science push version), gives rise to new technologies that are incorporated into innovative products, processes and services which, in turn, are exploited in economic activities. Alternatively the model is conceptualised in reverse whereby market forces (market pull version) pull through the outputs of basic research to meet market needs. In the linear model PROs, and the outputs of their activities in basic research, are key actors in the innovation process typically portrayed as the instigators of innovation through their development of new technologies.

However, empirical research over many years and in many sectors has demonstrated that the linear model does not adequately explain how innovation occurs in practice. Innovation, according to these studies, is a complex, non-linear and risky process, involving multiple feedback routes between processes, functions and people both internal and external to the firm. Innovation may be triggered, for example, not only by technological advances and market forces but also by users and consumers.[3]

Various alternative models of innovation have been developed to encompass the complexity of innovation in place of the linear model. The **chain-linked model**[4] highlights the role of design in innovation as well as the paths by which both internally and externally generated knowledge flows between the various stages of a firm's innovation activities - research, design and test, production and marketing. Compared to the linear model, the chain-linked model includes various feedbacks between different innovation activities and as such describes a much more complex innovation process. More recently the **open innovation**[5] model has conceptualised a more fluid process whereby a firm not only relies on both external as well as internal knowledge and expertise for innovative activities but also allows the knowledge it generates to flow outwards to those who can make best use of it. The assumption being that high-quality knowledge, useful to firms, is abundant and widespread and that firms (including those with sophisticated R&D departments) cannot possibly 'own' all the knowledge they require and should identify and utilise relevant knowledge from all sources. In particular it focuses on the concept of fluid or more open boundaries between the firm and other knowledge providers, enabling it to widen its 'search' activity through working in collaboration with others or buying or licensing in new technologies. However, a firm, according to this model, resorts to external knowledge only *as and when* needed.

[3] See, for instance, Jan Faberber, *A Guide to the Literature*, in: Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds.), The Oxford Handbook of Innovation, Oxford University Press, 2005; Benoît Godin, *The Linear Model of Innovation: The Historical Construction of an Analytical Framework*, Project on the History and Sociology and S&T Statistics. Working Paper No. 30, 2005, www.csiic.ca/PDF/Godin_30.pdf; and, Roy Rothwell, *Towards the Fifth-generation Innovation Process* International Marketing Review, 11 (1), 1994, 7-31

[4] S. J. Kline & N. Rosenberg, *An overview of innovation*. In R. Landau & N. Rosenberg (eds.), The Positive Sum Strategy: Harnessing Technology for Economic Growth. Washington, D.C.: National Academy Press, 1986

[5] Henry W. Chesbrough, *The Era of Open Innovation*, Sloan Management Review, 44 (3), 2003, 447-485 and *Open Innovation: A New Paradigm for Understanding Industrial Innovation*, in: Henry Chesbrough, Wim Vanhaverbeke and Joel West (eds.), *Open Innovation: Researching a New Paradigm,* Oxford: Oxford University Press, 2006, 1-10

The **systems of innovation** approach takes a wider viewpoint, seeking to explain the process of innovation and its dynamics in a systemic context and can be conceptualised and deployed at a range of different levels - national, regional and sectoral.[6] The model proposes that successful innovation depends on well-established relationships and close interaction between an innovative company and a number of external organisations involved in the innovation process and an 'institutional' environment conducive to innovation. As illustrated in Figure 1, external organisations include other firms (of suppliers, customers or competitors), universities, public research institutes and public innovation agencies. While the term 'institutions' refers to the 'basic rules of the game' as well as the broad legal framework and norms - it also includes common habits, routines and practices governing structures (e.g., financial institutions) or concrete entities (e.g., the Bank of England) as well as structures and forces enabling, or constraining complex interactions between actors.[7]

The linear model of innovation is now viewed largely as a simplification of a much more complex process, and the alternative models each have their place as tools to help understand and describe how innovation occurs within businesses (e.g. the chain-linked model) or at the national or regional level (e.g. systems of innovation) or as models for businesses implement (e.g. open innovation). There is no one size fits all model for all purposes. However from a policy perspective the innovation systems model are useful tools to help policy-makers analyse an innovation system (at national, regional or supra-national level) to determine where policy can improve its functionality.

Importantly, these models of innovation place **businesses firmly at the centre**, as the main actors in innovation. Businesses understand both their current markets and their own technological capabilities and skills and, therefore, are in a position to be able identify market needs and act to adapt, innovate and change to meet those needs. In these models, and inside real firms, innovation involves continuous interaction and feedbacks between perceptions of market opportunities, technological capabilities, and learning processes within firms. Research and development is often not the source of innovation – business R&D or otherwise - as firms aim to innovate by exploiting their existing technological capabilities and knowledge assets. In this scenario research and development plays a different role, not acting as a stimulus of innovation but providing a problem-solving capability within a wider innovation activity. In some more technological sectors R&D may also serve to identify problems that need solving (and once solved will be beneficial to customers).

Therefore, the 'research' function within firms can be viewed more as a 'search' function, looking for *internal* <u>*and*</u> *external* problems to solve and so providing opportunities for innovation.

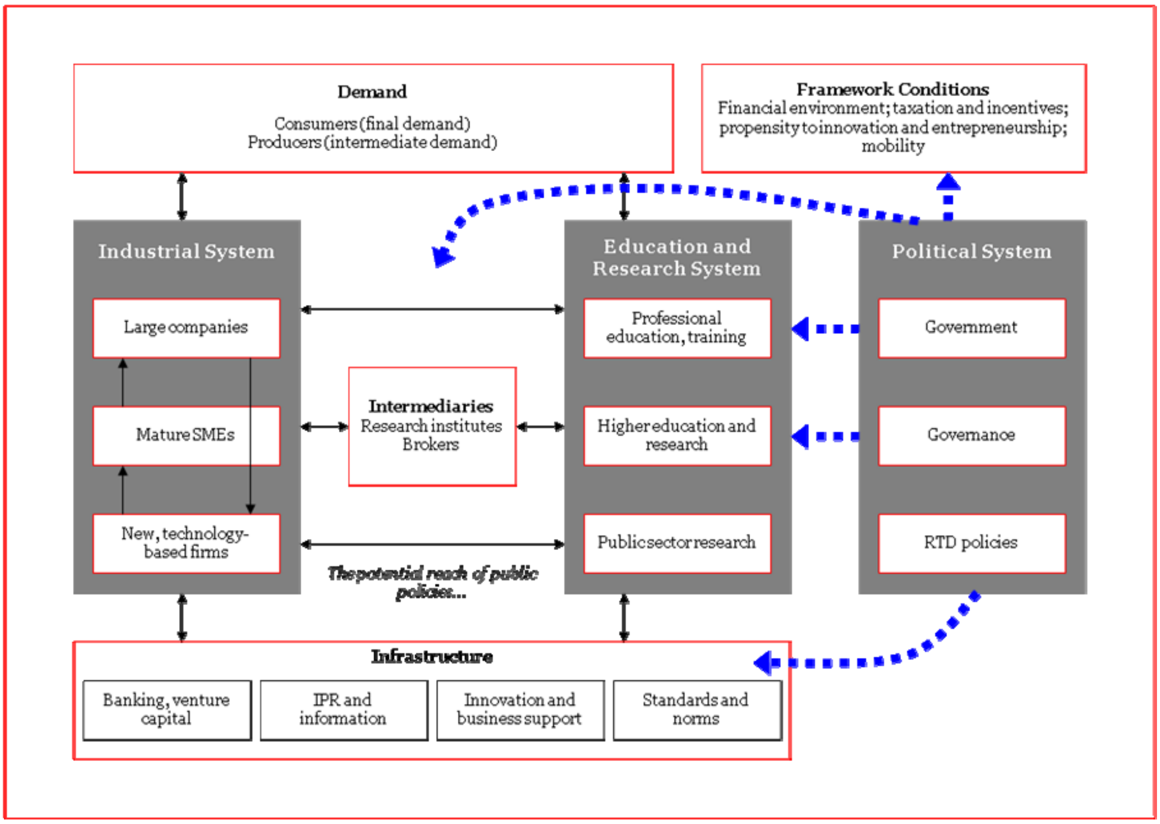
[6] Ake-Bengt Lundvall, *National Innovation System: Analytical Focusing Device and Policy Learning Tool*, Working Paper R2007:004, Ostersund: ITPS, Swedish Institute for Growth Policy Studies, 2007; and, OECD, *National Innovation Systems*, Paris: OECD Publications, 1997

Hans-Joachim Braczyk, Philip N. Cooke and Martin Hedenreich (eds.), *Regional innovation systems: the role of governances in a globalized world*, London: UCL Press, 1998

Franco Malerba (ed), *Sectoral Systems of Innovation: concepts, issues and analyses of six major sectors in Europe*, Cambridge: Cambridge University Press, 2004

[7] Douglass C. North, *Institutions, Institutional Change and Economic Performance*, Cambridge: Cambridge University Press, 1990; Charles Edquist, *The Systems of Innovation Approach and Innovation Policy: An account of the state of the art*, Paper presented at the Nelson and Winter DRUID Summer Conference, Aalborg Congress Center, Aalborg, Denmark, 12-15 June, 2001; Richard R. Nelson, *What enables rapid economic progress: What are the needed institutions,* Research Policy 37 (1), 2008, 1-11.

Figure 1 National innovation systems model[8]



2. Firms use of external knowledge

Firms' links to external knowledge sources enables them to both explore possibilities for innovation and to exploit knowledge to improve existing technologies, products and processes. Relationships with external sources are particularly important for accessing tacit knowledge - the knowledge that is not codified in documents (manuals, reports, scientific papers, patents etc.) and that embodies know-how, skills and expertise.[9] Tacit knowledge is not only important for its own sake, i.e. where codified knowledge does not exist, but is often an essential supplement to codified knowledge – to enable a full understanding of the information contained in a publication or patent or, more importantly, to facilitate the practical implementation of the knowledge in a different context. Furthermore tacit knowledge tends to be 'sticky' in that it does not flow readily between people. It may require demonstration, hands-on training or experience, and generally involves close interactions between individual knowledge holders (e.g. researchers at PROs) and potential new users (e.g. staff in businesses).

[8] Erik Arnold and Stefan Kuhlman, *RCN in the Norwegian Research and Innovation System*, Background Report No 12 in the Evaluation of the Research Council of Norway, Oslo: Royal Norwegian Ministry for Education, Research and Church Affairs, 2001. Also available at www.technopolis-group.com

[9] See, for instance, Eric von Hippel, *Sticky Information' and the Locus of Problem Solving: Implications for Innovation*, Management Science, 40 (4), 1994, 429-439; and Shaker A. Zahra and Gerard George, *Absorptive capacity: A review, reconceptualization and extension*, Academy of Management Review, 27 (2), 2002, 185-203

Firms can take in the required knowledge from wherever it can be found – in the open innovation model, for example, firms explicitly recognise that more knowledge resides outside the firm than can possibly reside within it and deliberately pursue that knowledge in conjunction with others. The source of any new knowledge is not a matter of great importance to the firm and solving innovation-related problems will require accessing knowledge and skills from outside the firm. Furthermore both knowledge and innovation capabilities are cumulative, building and growing over time and internal business R&D, while not universal, increases a firm's *absorptive capacity*,[10] i.e. its ability to access and assimilate external knowledge. Firms that do R&D internally are therefore also better equipped that others to make use of **external** knowledge.

3. Relationships and networks

To reach their innovation and growth related objectives, firms engage in several types of relationships with external sources of knowledge, be they other firms (suppliers, customers, service providers) or governmental and other organisations including universities and research institutes but also organisations such as regulatory bodies.[11] These relationships can be close or loose, formal or informal; they may be an extension of existing relationships with suppliers and customers or they may involve additional resources and activities to expand opportunities for accessing potential inputs to their innovation activities.

Proximity facilitates the development of relationships between firms and their external sources of information. Geographic proximity, for instance, enhances 'togetherness' and exchanges, while 'cognitive' proximity (i.e. a common knowledge base encompassing diverse but complementary capabilities) facilitates interactive learning, and, thus, innovation.[12]

Geographic proximity is the basis of sector or technology based clusters or industrial districts of interdependent firms and other organisations such as PROs, technology intermediaries such as RTOs, regulatory bodies. In clusters, formal and informal rules and enforcement procedures (that is, institutions) exist to regulate the activities of, and the flow of knowledge and information between, the cluster members. Formal relationships may be embodied in contracts – purchases, joint ventures, employment contracts etc. – while informal rules may reside in social norms that guide behaviour or influence levels of secrecy or openness in inter-firm relationships. Networks, by contrast, are more flexible structures bringing together both organisations and individuals with overlapping and complementary capabilities, and they may be defined by geography and/or cognitive proximity. Networks are largely based on openness, reciprocity and interdependence as well as on a common identity, reputation and trust rather than on formal rules and enforcement mechanisms.[13]

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[10] Cohen et al, and Daniel A. Levinthal, *Innovation and learning: The two phases of R&D*, the Economic Journal, 99, 1989, 569-596, 1989; and *Absorptive capacity: A new perspective on learning and innovation* Administrative Science Quarterly, 35, 1990, 128-152

[11] Frank Moulaert and Farid Sekia, *Territorial Innovation Models: A Critical Survey*, Regional Studies, 37 (3), 2003, 289-302

[12] Ron A. Boschma, *Proximity and innovation: A critical assessment,* Regional Studies, 39 (1), 61-74, 2005

[13] Walter W. Powell and Steine Grodal, *Networks of Innovators*, in: Jan Fagerberg, David C. Mowery and Richard R. Nelson (eds.), *The Oxford Handbook of Innovation*, Oxford University Press, 2005, 56-85

The literature reviewed points to considerable knowledge related benefits for firms and their innovativeness resulting from their participation in clusters and networks. These structures facilitate firms' access to new information and knowledge, including tacit knowledge, at a rapid pace and a lower cost. They also provide firms with access to human capital, namely skilled university graduates and researchers, which allows firms to acquire tacit knowledge. These, in turn, strengthen the knowledge base of firms, enhance their capacity to innovate and encourage the diffusion of innovation as well.

The existence of industrial districts and clusters, and their corresponding knowledge bases, is largely dependent on historical patterns of industrial development at the national and regional level, while levels of interaction, openness and exchange will be influenced by national, sector and disciplinary cultures and traditions. Therefore a firm's ability to take advantage of the knowledge opportunities offered by clusters and networks is dependent to some extent on its geographical context (its national or regional system of innovation) and its sector and technological basis.

4. Patterns of innovation in different sectors

The systems of innovation approach has been applied at the sector level enabling the identification of different approaches to innovation. Empirical work in the 1980s assessing sources and flows of innovation, as well as the characteristics of innovating firms identified five distinct patterns of innovation behaviour at the sector level.[14] A significant feature of the patterns is that sources of technology not only vary by sector, but that technology, (embodied in innovative products) flows within and between sectors, reflecting the diverse ways in which technologies are created and diffused through the economy.

The work resulted in the definition of a sector innovation taxonomy based upon four key features: sources of technical change; focus of innovative activity (e.g. product or process innovation); size of innovating firms; and the means of appropriation of the benefits of investments in innovation. The five categories of the taxonomy are described in **Figure 2**. It is intended as a useful analytical tool and although examples of sectors in each category are given it does not imply that all firms in those sectors necessarily correspond to that category or that all firms in a sector are innovation active.

Importantly, **Figure 2** shows that most categories rely to a great extent on incremental change and the accumulation of technological skills and know-how over time. The sources of innovation inputs are varied, coming from a range of sources both internal and external to the firm, typically from in-house production engineering and design and from external suppliers and users, with very few relying on in-house or external R&D. Furthermore, a range of different methods are used in across the categories to appropriate innovations, including secrecy and in-house know-how as well as formal intellectual property such as patents, trademarks and copyright.

Only one category, science-based firms, has a strong reliance on fundamental developments in basic science and as a consequence reasonably close ties with PROs. These are also the firms that most frequently make use of formal intellectual property, in the form of patents, as a key tool to protect innovations to ensure competitive advantage and ensure the recovery of R&D investments. Therefore this category not only most closely matches the linear model of innovation, it also aligns with the early concepts of *technology transfer* from PROs via patents and licensing. This category includes sectors such as pharmaceuticals, chemicals and parts of electronics.

[14] Original study: Pavitt, K. (1984) *Sectoral patterns of technical change: towards a taxonomy and a theory*, Research Policy, Vol. 13, pp.343-373. This work was updated and modified in 2001: Tidd, J., Bessant, J. & Pavitt K., (2001) *Managing innovation integrating technological, market and organisational change.* 2nd ed. Wiley, Chapter 5

PRO spin-outs, based on intellectual property developed in PROs, typically fall into the specialised supplier category (at least initially) supplying technology, instrumentation, or new materials, for example, to their customers and supporting the innovation processes in other sectors. This is not to say that truly disruptive game-changing innovations, which might be developed by spinouts, do not occur. However, in practice such innovations are much more infrequent than is generally believed.

Companies in other sectors rely on external inputs from PROs to a much lesser extent. Scale-intensive sectors such as automotive, bulk materials and consumer durables focus on both process and product innovation and may seek external inputs when internal skills and knowledge are not sufficient. Change tends to be incremental as significant investments in plant and products have already been made and therefore interactions with PROs, where they occur, are more likely to involve engineering departments, applied science and perhaps business schools to solve existing problems and to widen their search for relevant future developments. These firms will also benefit from innovations developed by their supply-chain who may themselves interact with PROs to develop and improve instrumentation for example. Similarly, firms in the supplier-dominated category, by definition, rely on their supply-chain for innovations and they may well also benefit from their suppliers' interactions with PROs.

Figure 2 Taxonomy of sector innovation[15]

Category	Main sources of technical change	Focus of innovative activity	Size of innovating firms	Means of appropriation
Supplier-dominated	11. Suppliers 12. Production learning Firms are almost entirely dependent on their suppliers of machinery and other production inputs for new technologies Limited in-house innovation activity is undertaken but some learning from in-house production activities	Main focus is process innovation in pursuit of cost reductions Innovation strategy is to use to technology from elsewhere to support competitive advantage. Process innovations are created in supply sectors and embedded within the inputs to production	Firms are typically small and found within traditional manufacturing sectors such as ***textiles, agriculture and services***	Appropriation is rarely based on technological advantage but instead on professional skills: 13. Design 14. Trademark 15. Advertising 16. Marketing
Scale-intensive	17. Production engineering 18. Production learning 19. Design office 20. May include in-house R&D 21. Suppliers Innovations are largely developed in-house, which may include an internal R&D. Some innovation also sourced from specialised suppliers of equipment and components	Both product and process innovation but a significant focus on production improvements. Innovation strategy is focused on incremental improvements as implementing radical change on complex products and processes is highly risky	Firms are characterised by large-scale mass production where significant economies of scale and division of labour are present. The products & production systems are complex integrations of technologies. Sectors include*: **automobiles, extraction & processing of bulk materials & consumer durables***	Appropriation by: 22. Process secrecy and know-how 23. Technical leadership 24. Some patenting
Specialised-suppliers	25. Design function 26. Operational knowledge 27. Input from advanced users	Innovation focused on product performance improvements. These improvements are often developed to meet the high specification requirements of key users. They are later transferred to other users	They are generally small in size, manufacturing high-performance inputs to other complex products and production processes – inputs such as machinery, components, instrumentation and software	Appropriation by 28. Design know-how 29. Relationships with, and knowledge of users 30. Some use of patents
Science-based	31. In-house R&D 32. Basic research from external sources 33. Input from advanced users These firms invest heavily in internal R&D to create innovative new products and have close ties to the research base to access new knowledge, skills and techniques	Focus on product innovation where fundamental discoveries (in basic science) lead to new products and markets and corresponding new production and organisational processes Innovation strategy requires monitoring and exploiting developments from the research base	Innovation is highly dependent on developments in the relevant science base and new products are diffused widely as consumer goods or inputs to other sectors Firms are typically large and in sectors such as ***pharmaceuticals, chemicals, electronics, materials***	Appropriation by: 34. R&D know-how 35. Patents 36. Process secrecy and know-how 37. Internal dynamic learning
Information-intensive	38. In-house systems & software departments 39. Suppliers Innovation comes from internal and external sources, and is based on IT hardware	The focus of innovation is to improve, and even redefine, methods of service delivery and to create entirely new service products	Firms are in service sectors that rely heavily on technology to process large quantities of information for efficient and effective service delivery: sectors such as ***finance, retail, insurance, travel and publishing,***	Appropriation by: 40. Process know-how 41. Software IP (copyright) 42. System design

[15] Pavitt, K. (1984) *Sectoral patterns of technical change: towards a taxonomy and a theory*, Research Policy, Vol. 13, pp.343-373; Tidd, J., Bessant, J. & Pavitt K., (2001) *Managing innovation integrating technological, market and organisational change.* 2nd ed. Wiley, Chapter 5

	improvements, software developments and systems integration		***telecoms***	know-how

Sources of external knowledge are varied and evidence suggests that inter-firm co-operation is the most important channel for knowledge acquisition, exchange and sharing and that a firm's customers, suppliers and competitors, rather than PROs, are the most dominant external knowledge sources cited by businesses. The data from the Community Innovation Survey reinforce this point, with universities and public research organisations being cited as sources of knowledge or information for innovation activities by only 15% of firms and cited as a 'highly important' source by less than 6% of firms.[16] Furthermore, only a small proportion collaborate with PROs on a regular basis and, as the sectoral models of innovation illustrates, the firms that do make use of knowledge from PROs are more likely to come from some sectors than others.

1. Summary

How innovation occurs

43. **Businesses are the main actors in innovation** and their ability to innovate successfully is determined by:

44. Their internal capabilities to identify opportunities and develop solutions and their capacity to 'absorb' knowledge from external sources

45. By their 'embeddedness' in a structure, or network, of relationships with other innovation actors that enable them to seek and access external inputs

46. By their location in a wider economic and social system conducive to innovation

47. Businesses are at the centre of an innovation process that involves continuous interaction and feedbacks between perceptions of market opportunities, technological capabilities, and learning processes

48. Businesses make use of a wide range of inputs to innovation; both from internal sources - that are much wider than just in-house R&D, and from external sources – most typically from their suppliers and also from customers. PROs are just one source of many external inputs to firms' innovation processes and, in general, they are used to a much lesser extent than other sources.

49. Some sectors will be more predisposed to work with PROs than others. Science-based firms in sectors such as pharmaceuticals, electronics, chemicals and materials rely on developments in fundamental science and as a result have the closest ties with PROs.

50. Not all sectors make use of formal intellectual property as a method to appropriate innovations. Science-based sectors tend to use intellectual property in the form of patents to protect their innovations – to ensure a sufficient return on their R&D investments (e.g. pharmaceuticals) and/ to secure market leadership (e.g. electronics). While other sectors use a range of mechanisms for protection: the software sector tends to use copyright; while firms that rely on inputs from suppliers protect their innovations by design, trademarks, marketing and advertising; and secrecy, internal know-how and technological leadership also have a role to play.

51. Therefore the proportion of innovation active firms that are willing and able to engage with PROs via a technology transfer model focused on the exploitation of formal IP is somewhat limited and, moreover, different knowledge transfer mechanisms will be required for sectors that do not rely on IP.

52. Furthermore the pattern of historical industrial development and the resultant sectoral structure at the national and regional level, as well as national cultures and norms, will influence the extent of interaction between firms and PROs.

[16] Sergiu-Valentin Parvan, *Community Innovation Statistics: Weak link between innovative enterprises and public research institutes/universities*, Statistics in Focus, Science and Technology, 81/2007

53. The Role of PROs in Innovation

1. Knowledge transfer mechanisms

The early European public policies (in the late 1980s to mid 1990s) directed at the role of PROs in innovation concentrated on the transfer of *technology* in the form of formal intellectual property. The focus was on protecting research outputs with commercial potential through patenting (in particular) followed either by the licensing of patents to businesses for commercialisation or establishing spin-outs to conduct the commercialisation process. These policies were essentially based on the linear model of innovation and focused largely on technology push from PROs to industry. However as a more systemic model of the innovation process has emerged, along with increased practical experience of knowledge transfer from PROs, a deeper and more sophisticated understanding of the role of PROs has developed. The need for new knowledge versus problem-solving capabilities, the need for both codified and tacit knowledge, the absorptive capacity of different sectors and individual businesses and differences in sectoral patterns of innovation all influence ***how*** businesses interact with PROs.

The literature and the evidence from the case studies suggest that mechanisms for accessing and transferring knowledge can be grouped into seven categories with each mechanism transferring different types (or combination of types) of knowledge. The figures below present the knowledge transfer mechanisms (Figure 3), types of knowledge (Figure 4) and the types of knowledge transferred by the different KT mechanisms (Figure 5).

As Figure 3 illustrates, access to codified research outputs is made available via the traditional ***publications*** of the academic profession – articles in journals, books, monographs, conference proceedings etc. Firms can also access and exploit codified knowledge embodied in formal ***intellectual property*** *(IP)*, most commonly patents via purchase or licensing of IP. IP generated by PROs can also be made available to the market through the establishment of new businesses (spin-outs) to develop and sell the technology. Where these businesses continue to work with PRO researchers as employees or consultants, they also gain access to the tacit knowledge associated with the IP.

Firms can procure research outputs specific to their needs via ***consultancy and contract R&D*** at PROs. This may be to solve specific existing problems or as part of the 'search' activity in their innovation process and may involve the application of existing knowledge (consultancy) or the generation of new knowledge (contract R&D) to identify solutions. This mechanism tends to result in the transfer of codified knowledge in reports focused on the clients' specific problems or interests or knowledge embodied in artefacts or instrumentation. Some tacit knowledge may be transferred depending on the level of engagement between researchers and clients. Firms can elect to work even more closely with researchers on research areas of mutual interest through jointly funded and jointly conducted ***formal collaborative R&D*** projects. These might be one-to-one projects negotiated directly between a PRO and a firm or projects stimulated through public research funding programmes involving a larger group of PRO and industry partners in so-called 'pre-competitive' research. While individual research projects may last anywhere between one to five years, collaborative R&D may also involve much longer term research relationships centred on 'competence centres' (part funded by the public and private sectors) such as the Engineering Research Centres in the USA or the Swedish Competence Centres, that develop 5-10 year research strategies in, typically, basic research of mutual industry and academic interest. This type of shared funding, design and implementation of research activities across both the research base and industrial locations enables a two-way transfer of tacit as well as codified and embodied knowledge not only between PROs and industry and also between industry partners who may be different actors in a value-chain or from different sectors that use similar technologies or encounter similar problems.

Firms and PROs may also engage in more ***informal collaboration*** to transfer (primarily) tacit knowledge through personal relationships and professional associations or through participation conferences and other events. These tend to be more ad-hoc interactions either sought out for specific reasons or through the general participation in the activities of similar professional or disciplinary communities. In some cases, specific networks are created by professional associations or public policy to bring together those with common interests in order to facilitate knowledge sharing and problem solving.

Finally firms may access codified and tacit knowledge through proactively supporting the development of ***research skills*** by recruiting post-graduates with Masters and PhD level research skills, funding Masters and PhD students, supporting joint PRO-industry positions or temporary staff exchanges.

Figure 3 Knowledge transfer mechanisms[17]

	Mechanism	Description
1	**Publications**	54. Publications in referred journals / books 55. Other reports / publications 56. Open source publication 57. Presentations at conferences 58. Patent texts
2	**Exploiting intellectual property**	Disclosure of PRO generated IP and its commercialisation through: 59. Selling IP 60. Licensing IP (particularly patents) to companies for commercialisation 61. Creating spin-outs based on PRO IP (typically licensed to the spin-out) and involving PRO personnel/ faculty
3	**Contract R&D and consultancy**	62. Contract R&D: formal contract between a company and a PRO, for the PRO to conduct novel research to create **new knowledge** on behalf of a business 63. Consultancy: formal contract between a company and a PRO for PRO personnel to apply **existing knowledge** to company's business (e.g. advice, written reports, technical adaptation) 64. Technical services: e.g. testing / characterisation services etc. using PRO facilities to provide data / information
4	**Formal collaboration/ partnerships**	65. University-industry collaborative research partnerships typically encouraged and supported (in part) with public funds 66. Joint (research) ventures between PRO and a company) 67. Groups of companies and universities / PROs engaged in longer-term research partnerships of common interest such as competence centres
5	**Informal interactions**	Informal / personal exchanges with links made through a variety of means: 68. Personal contacts 69. Alumni organisations 70. Professional organisations 71. Participation in conferences / seminars
6	**Accessing research skills**	72. Hiring higher-level graduates (Masters/ PhD) 73. Financing of PhD projects 74. Student internships in business 75. Temporary staff exchanges / visits 76. Staff holding joint positions in PRO and industry
7	**Other mechanism(s)**	For example: 77. Training / continuing professional development 78. Sharing facilities 79. Exchange of research materials 80. Public events / open days

[17] Based on: Wesley M. Cohen, Richard R. Nelson and John P. Walsh, *Links and Impacts: The Influence of Public Research on Industrial R&D*, Management Science, 48 (1), 2002, 1-23; Gillian McFadzean, *A comparison of different exploitation methods (e.g. licensing, selling, spin-outs) as means to extract value form research results: why do people or organisations choose certain routes for the exploitation of research results?*, European Commission 2009 Expert Group on Knowledge Transfer (2009); Arianna Martinelli, Martin Meyer, Nick von Tunzelmann, *Becoming an entrepreneurial university? A case study of knowledge exchange mechanisms and faculty attitudes in a medium-sized, research-oriented university*. Journal of Technology Transfer, Vol. 33, pp 259-283, 2008; Ajay Agrawal, Rebecca Henderson, *Putting patents in context: exploring knowledge transfer from MIT*, Management Science, Vol. 48 no. 1, pp 44-60, 2002

Figure 4 Types of knowledge[18]

Type of knowledge		Examples
Codified (explicit)	Protectable/ formal intellectual property	Patents Copyright Registered /unregistered designs Trademarks
	'Soft' intellectual property	Uncopyrighted software Databases Materials (not patented or trademarked) Research questionnaires Research methodologies
	Publications	Referred journals and other academic publications such as books, monographs, conference proceedings (most of which are also covered by copyright)
	Open source publications	Publications/ online sources not covered by copyright
Tacit	Know-how	Skills Techniques Complex cumulative knowledge plus conceptual models and terminology
Embedded	Physical manifestations of knowledge (artefacts)	Instrumentation Materials e.g. samples of new materials, cell lines

Figure 5 Types of knowledge transferred by each KT mechanism[19]

Knowledge transfer mechanism	Sub-category	Type of knowledge transferred
Publications	n/a	(Existing) codified knowledge
Exploiting intellectual property	Selling / licensing IP	Codified knowledge
	Spin-outs	Codified and tacit knowledge
Contract R&D and consultancy	Contract R&D	(New) codified, embedded knowledge (tacit knowledge in some cases)
	Consultancy	(Existing) codified knowledge (tacit knowledge in some cases)
	Technical services	Codified and/or embedded knowledge
Formal collaboration/ partnerships	n/a	Tacit knowledge, codified knowledge (existing and new), embedded knowledge (if any created)
Informal interactions	n/a	Tacit knowledge
Accessing research skills	n/a	Tacit knowledge
Other mechanisms	e.g. training	Tacit knowledge

[18] Constructed by Technopolis based on: Erik von Hippel, *The dominant role of users in the scientific instrument innovation process*, Research Policy 5 (3), 1976, 212-239 and *Successful industrial products from customer ideas*, Journal of Marketing, 42 (4), 1978, 39-49; Brigitte Anderson and Frederica Rossi , *The flow of knowledge from the academic research base into the economy: the use and effectiveness of formals IPRs and 'soft' IP in UK universities*, A report to the Strategic Advisory Board for Intellectual Property Policy, Intellectual Property Office , Oct 2010

[19] Constructed by Technopolis based on: Anderson, op.cit. (2010), Bekkers, op. cit. (2010)

1. Relative importance of different knowledge transfer mechanisms

A number of empirical studies have investigated the importance of different KT mechanisms from the perspective of both industry and PRO researchers.[20] Theses studies demonstrate that the most important knowledge transfer mechanisms, for manufacturing firms and those with some level of in-house R&D, are a combination of the traditional outputs of academic research, that is publications such as journal articles and conference proceedings, plus informal interactions such as personal contacts, conferences and seminars. For both industry and PROs contract and collaborative R&D and consultancy fall in the middle ground, while exploiting IP is of considerably less importance – albeit ranked slightly more important by industry than PROs. This is not to suggest that exploiting IP generated by PROs is not important, but that it needs to be understood as part of a much wider knowledge transfer system. (Appendix C provides a more detailed analysis of the published empirical research.)

The studies show that IP exploitation is of greater importance for a few science-based sectors, such as pharmaceuticals, chemicals and parts of electronics, that is the sectors that are highly dependent on scientific advances and rely on patents as a source of competitive advantage. This finding is reinforced by studies of the patenting and licensing behaviour of PROs. In the late 1980s drugs and medicine were the largest field in which universities in the USA patented, making up around 35% of all university patents, followed by chemicals (20-25%), electronics (20-25%) and mechanical technologies (10-15%).[21] The importance of pharmaceuticals, biotechnology and medical technologies has remained a consistent pattern in both the USA and Europe. Three quarters of Belgian university patents in the period 1985-99 were in biotechnology related fields.[22] In Denmark between 1978 and 2003, 51% of university patents were taken out in pharmaceuticals and biotechnology, followed by 17% in instruments and then 11% in electronics.[23] The more recent 2007 AUTM survey in the USA reported that 25% of all university patents were in 'therapeutic and medical devices'.[24] The analysis of patenting behaviour of European PROs in the phase 1 of the study further reinforces this point, with the majority of patents being in fields related to the medicines and healthcare via developments in life sciences and chemistry (i.e. science-based industries), followed by new instrumentation and measurement techniques, developed in by specialist-suppliers and deployed in a range of sectors (Appendix E).

[20] Cohen at al. op.cit. (2002); Bekkers et al, op. cit. (2008), Martinelli et al, op. cit. (2008); Ajay Agrawal et al, op. cit. (2002)

[21] R. Henderson, A. Jaffe, and M. Trajtenberg. *Universities as a source of commercial technology: a detailed analysis of university patenting*, 1965-1988. Review of Economics and Statistics 80:119-127. 1998

[22] Eleftherios Sapsalis and Bruno van Pottelsberghe de la Potterie, *Insight into the patenting performance of Belgian universities*, *Brussels Economic Review*, 46 (3), 2003, 37-58

[23] Peter Lotz, Francesco Lissoni, Jens Schovsbo and Adele Treccani, *Academic patenting and the professor's privilege,* DRUID Conference, 2009

[24] *AUTM US Licensing activity survey; survey summary FY 2007*, AUTM, 2007

The case studies report a similar pattern, with most patenting activity arising in disciplines most aligned with patenting sectors, that is in the life and physical sciences. For example: 65% of patent activity at the University Libre Bruxelles is in the life sciences; at the University of Milan the majority of its patent activities are in the life (21%) and physical sciences (40%) and just over half of its spin-outs are in life sciences/pharmaceuticals. Similarly, the patenting activity of the KTO at the University of Oxford is divided roughly equally between outputs from the life and physical science faculties and a significant proportion of its spin-outs are in the life sciences. All of these universities have a relatively broad disciplinary base and so there is not an inherent bias towards specific disciplines or sectors. However it is important to note that the science-based sectors make use of a range of KT mechanisms, not just IP exploitation, and view these other mechanisms as important.

These findings align fairly closely with the taxonomy of sector-innovation models (Figure 2) in that the science-based sectors, i.e. the sectors that the taxonomy identified as having close-links to the science-base and using patents to appropriate innovations, such as pharmaceuticals, electronics, chemicals, make the most use of IP from PROs. Other sectors engage with PROs in other ways making use of publications, consultancy, contract /collaborative R&D etc. but rarely make use of PRO generated IP.

In practice (as reported by KTO staff) individual companies with fairly intensive interactions with PROs make use of a range of KT mechanisms - using different mechanisms to initiate interactions with PROs and then develop long-term relationships with relevant academics and research groups to access both codified and tacit knowledge. Publications, for example, may help identify the key players in a field and informal interactions at a conference or seminar might be the first step in an interaction. A closer relationship might start with a consultancy or contract R&D project to solve a particular relatively short-term problem. Opportunities for collaborative R&D may arise as a greater understanding is gained of each others' skills, needs and motivations and a deeper level of trust has been developed and later, such projects might result in IP that the industry partner can exploit.

In fact, licensees of PRO-generated IP tend to be organisations already known to the PRO and are, therefore the culmination of longer-term relationships. MIT reports, for example, that the majority of licences (of the order of 70%) are executed with commercial entities already known by the inventor.[25] Furthermore, the exploitation of PRO-generated IP, which is typically at a very early stage of development, usually requires further input from academic researchers during the development and (if successful) eventual commercialisation phases. This can take the form of collaborative R&D, contract R&D or consultancy that facilitate the transfer of 'softer' forms of knowledge such as tacit knowledge and know-how. It is relatively unusual for a licence agreement with a PRO not to involve interactions and further knowledge transfer between the licensee and the researcher whose work underpins the patent.

Research suggests that IP licensing can also be the starting point for a relationship; here published patents are used to identify who to work with (e.g. through patent scanning) and licensing is used as a method to instigate and then develop relationships with academics.[26]

[25] Inventor's Guide to Tech Transfer outlines the essential elements of technology transfer at the Massachusetts Institute of Technology. Technology Licensing Office, MIT, 2005

[26] Ahmad Rahal, *University technology buyers, a glimpse into their thoughts*, Journal of Technology Management and Innovation, Vol. 3, Issues 1, pp 38-41, 208

Moreover the literature also shows that it is not simply the sector that defines how firms interact with PROs but the disciplines with which they interact and the characteristics of the knowledge and organisations involved.[27] Labour mobility, for example, is important when knowledge breakthroughs are expected and when less knowledge is susceptible to being codified. Collaborative and contract research is important for transferring both codifiable knowledge as well as systemic and interdependent knowledge; these routes also appear to be more important for medium and large firms (presumably as they have the internal R&D budgets to engage in this way) and less important for physics and chemistry but more important for medical science, chemical engineering and computer sciences. The key point made by the researchers is that while certain patterns of factors tend to align with certain sectors they may also be present in individual firms and therefore a simplistic sector approach may not be appropriate for all firms in a sector. The case studies confirm this, with the KTOs who have responsibility for a wide range of KT mechanisms, reporting that the most appropriate form of interaction with any individual company is selected on a case-by-case basis.

While the empirical studies have concentrated on manufacturing firms and those with some level of in-house R&D, the results are more generally important to a consideration of knowledge transfer, because these are the very firms that might be expected to be most interested in accessing formal IP. And, if the non-IP mechanisms are important for these firms, they can only be expected to be even more relevant and important for those firms and sectors with little interest in formal IP. Consequently, IP exploitation alone will only ever be a comparatively minor part of the knowledge that flows between PROs and businesses.

The range of different mechanisms used by firms demonstrates that once relationships have been developed, PROs become part of a company's innovation network – facilitating informal interactions and building relationships and reputations that may lead, over time, to more formal interactions and deeper trust-based relationships. Developing a strong position and a reputation for effective interactions with industry within a network takes time and as an approach to knowledge transfer is in almost complete opposition to the concept of selling or licensing IP to the highest bidder from an all-purpose technology transfer 'shop window'.

In summary, the KT mechanisms ranked in order of importance by both industry and academics are as follows:

81. The traditional published academic outputs such as journal articles, conference proceedings and books
82. Informal interactions including interactions at conferences, seminars and via professional associations as well as personal contacts and relationships
83. More in depth research relationships – including contract research, consultancy, collaborative R&D and accessing research skills (through funding PhDs etc.)
84. Exploiting PRO IP through licensing patents, copyright etc.

[27] Bekkers et al, op. cit. (2008)

1. Is there any conflict between KT mechanisms?

There has been considerable concern that increased engagement with industry, and the protection of PRO research outputs by patenting in particular, would undermine the traditional academic values, such as openness, and compromise the independence of academic research.[28] There is also widespread suspicion – notably among those who do not patent – that patenting distorts research into an applied direction. The empirical evidence is somewhat mixed and falls into two broad categories.

There is, in fact, no serious evidence that patenting impedes publication or the quality of research conducted at PROs. Recent evidence reveals that there is considerable complementarity between patenting and publishing as well as between the patenting and other KT mechanisms, notably, collaborative and contract R&D, consultancy, and joint PhD training. This is the case, for example, in technology areas related to chemistry, computer science and sub-fields of engineering and physics.[29] A survey of Italian academics found that those who published most in the scientific literature also patented the most.[30] A study of Norwegian faculty found that those in receipt of industrial funding publish more than other researchers.[31] Crespi et al[32] have shown that publication and patenting are complementary activities up to a maximum point, beyond which patents begin to substitute for publications. They also found that high levels of scientific production and contract research are both conducive to patenting. Broadly, therefore, they conclude that "top researchers succeed to publish and patent a lot; a high patent output does not seem to affect negatively the publication output of the most prolific researchers."

The second issue relates specifically to the use of patents by PROs. The concern arises on the industrial side of PRO-industry relations where some companies have found that the behaviour of the KTO towards patenting and licensing can sometimes impede commercialisation. Through a combination of over-valuing their IP, a desire (and targets) for PRO spin-outs and inexperience in IP management and commercialisation, KTOs can become a barrier to efficient and effective industry engagement. This is a result, in part, of a view held by both policy-makers and PROs themselves that IP commercialisation is a potential income stream for PROs rather than as part of their public good role to make their knowledge available for societal benefit. IP protection of PRO generated knowledge was initially intended to act as an *incentive to industry* to invest in the commercialisation of PRO knowledge, (something that, in most cases, PROs have neither the skills nor experience to do well). However the evidence suggests that those experiencing difficulties tended to be small companies and short projects, suggesting that larger companies with more experience are more able to work with universities despite these IP issues.[33]

[28] Richard R. Nelson, "The market economy and the scientific commons," *Research Policy*, 33 (3), 2004, 455-472

[29] Gustavo Crespi, Pablo D'Este, Roberto Fontana and Aldo Geuna, *The Impact of Academic Patenting on University Research and its Transfer*, SPRU Electronic working Paper Series No. 178, Sussex University: SPRU, 2008.

[30] Valentina Tartari and Stefano Breschi, "Set them free: Scientists' perceptions of benefits and cost of university-industry research collaboration" DRUD Conference, 2009

[31] Magnus Gulbrandsen and Jens-Christian Smeby, "The external orientation of university researchers and implications for academic performance and management," *Science and Public Policy*, 2003

[32] Crespi et al, op. cit. (2009)

[33] Hall, B. H., Link, A. N., Scott, J. T. (2001). Barriers inhibiting industry from partnering with universities: evidence from the Advanced Technology Program. *Journal of Technology Transfer*, 26(1), 87-98.

Furthermore those PROs with more experienced KTOs tend to have fewer problems striking suitable IP deals, suggesting that many go through 'teething problems' as they learn to take on a new role. However it is important that KTOs do not become barriers to PRO-industry interactions through taking inappropriately protective IP positions. The majority of knowledge transfer relies on interactions of individual researchers and industrialists, with the KTO acting as a bridge or facilitator. The individual interactions form parts of networks that constantly configure and reconfigure into a succession of functioning 'innovation systems' or cooperative networks.[34] If KTOs become barriers this will not only limit the potential for new interactions but may also damage the networks.

There is no evidence as yet to suggest that proactive knowledge transfer activity, through patenting or other mechanisms, is pushing research in a more applied direction. The fact that industry seeks to work with high quality academic institutions across a wide range of disciplines would suggest otherwise.

It is also important to note that, in many if not most fields, university-industry links improve research performance. A UK study indicates that – except in the specific case of IP exploitation – most academics engage with industry to further their research rather than to commercialise their knowledge.[35] Industrial interaction provides important signals about what problems are of practical and industrial interest in research terms, as well as often leading to the provision of resources.[36] Therefore knowledge transfer is not simply a one-way exchange as there are benefits to be gained from the flow of knowledge in both directions. Several of the PROs in our sample now refer to engagement with industry as 'knowledge exchange' rather than knowledge transfer to recognise this two-way flow. Furthermore, the term 'knowledge exchange' is starting to replace 'knowledge transfer' among policy-makers indicating a wider recognition of the interactivity and exchange in PRO-business engagements.

Therefore the empirical literature suggests that there are strong linkages between research productivity and patenting activity. In our sample, the most successful PROs in terms of IP exploitation tend to be the large research-intensive institutions who have been active in IP exploitation for 20-25 years. These are also the institutions with significant industrial research income, again reinforcing that patenting activity does not substitute for other forms of industrial engagement. These PROs have significant experience in IP exploitation and other forms of industrial engagement and have developed a knowledge transfer system that does not appear to impede interactions.

More generally, the empirical literature and our case studies, demonstrate that businesses make use of a range of KT mechanisms simultaneously and at different times reinforcing the conclusion that KT mechanisms are complementary rather than substitutes.

[34] Paul David and J Sanley Metcalfe, "Only Connect: Academic-Business Research Collaborations and the Formation of Ecologies of Innovation, SIEPR Discussion Paper 07-33, Stanford Institute for Economic Policy Research, January 2008

[35] Pablo D'Este and Markus Perkman, "Why do academics engage with industry? The entrepreneurial university and individual motivations," *Journal of Technology Transfer* (forthcoming)

[36] Edwin Mansfield, "Academic research underlying industrial innovations: Sources, characteristics and financing," *Review of Economics and Statistics*, 77 (1), 1995, 55-65; Siegel *et al.*, op. cit., 2003

2. The effects of knowledge transfer

The link between publicly funded research and economic and social impact is notoriously difficult to demonstrate due to the timescales involved, the multifarious inputs required (skills, actors, financial inputs and types of knowledge) to undertake innovation based on PRO outputs, and the risks involved. It is therefore not a simple task to identify the societal effects of different KT mechanisms – not least, as described above, as businesses that interact with PROs tend to make use of more than one mechanism, making distinctions between mechanisms difficult. We found nothing in the literature that assessed the relative impacts of the different mechanisms.

Instead we have developed a relatively simple model to describe qualitatively the effects of the different KT mechanisms on the different actors involved: PROs themselves, industry (in both the near and long term), and on society as a whole. The model is presented in Figure 6.[37] It provides estimates of the volume and the depth of the activity for each type of mechanism. The volume is estimated for Europe and the depth (i.e. the intensity of the interaction) is estimated for each individual interaction.

The KT mechanisms are ordered in terms of the number of unique interactions from highest to lowest. It is assumed that informal interactions are the most numerous although the actual number is unknown and is, in fact, probably unknowable. Around 500,000 research papers were published in 2011[38] with further conference proceedings, monographs, books etc. published. The number of articles read by industry will be a sub-set of the total (as they conduct their search for innovation opportunities) but it can be presumed that publications of interest may lead to further engagement with PROs from informal interactions to perhaps deeper forms of interaction – leading to new ideas and opportunities for innovation, with some innovation activities resulting in business growth. From the PRO perspective publications are their key research output, disseminating new knowledge and enhancing their reputation. For society as a whole they represent an increase in the stock of knowledge and make it publicly available and so making research spillovers possible. Informal interactions increase the opportunities for spillovers to occur.

Consultancy and contract R&D occur at a reasonable volume (the volume has been estimated from two sources yielding similar results) but each individual interaction is relatively small. Consultancy is most frequent but very short-term and very small-scale (for example, the annual UK survey of knowledge transfer activity reports the average consultancy and contract R&D activity to be €4,500 and €32,000 respectively).[39] These activities tend to solve current problems using existing knowledge – where that knowledge is packaged to answer specific questions. For the business it can contribute to innovation and, if the innovation is successful, it may contribute to business growth. It also helps maintain or develop relationships with PROs which enhance the innovation networks within which it operates.

[37] Estimates are based on a number of sources including: PACEC, *Evaluation of the effectiveness and role of HEFCE/OSI third stream funding*, Report to HEFCE by PACEC and the Centre for Business Research, University of Cambridge, 2009; Anthony Arundel and Catalina Bordoy, *Summary respondent report: ASTP survey for fiscal year 2008*, UNU-MERIT report for the Association of European Science and Technology Transfer Professionals, January 2010; Nature, http://www.nature.com/news/365-days-2011-in-review-1.9684; the number of FP7 projects started annually

[38] Nature, op. cit. (2011)

[39] PACEC and the Centre for Business Research, University of Cambridge, *Evaluation of the effectiveness and role of HEFCE/OSI third stream funding*, HEFCE, April 2009

Contract R&D has similar effects, but with a deeper interaction and the prospect of creating new knowledge. If there is a level of direct engagement during the project then tacit knowledge and skills may also be transferred. From a societal perspective both mechanisms increase the potential for innovation and business growth. It should be noted that innovation may also be necessary to protect existing revenue, jobs and profits within a competitive market.

Collaborative R&D involves a much longer and deeper interaction – either as a one-to-one partnership between a PRO and company or a multi-party collaboration conducting pre-competitive and/or cross-sector research, and therefore these happen at lower volumes but at a more significant scale. Projects are usually co-funded from public and private sources and may last anywhere between 3 and 5 years, for R&D projects, or 5-10 years for multi-party 'competence centres'. From a business perspective, it not only enables access to new knowledge and innovation opportunities in an area considered important, it also provides access to skills (and potential future research staff), new technological capabilities and new business relationships with other partners. For PROs, collaborative R&D provides the opportunity to conduct basic or applied research, gaining insight into industrial needs and interesting research problems. Collaborative R&D offers society the potential to gain the widest set of benefits – new knowledge and the potential for spillovers, more embedded innovation networks and ultimately more innovative businesses.

Patenting and licensing if conducted in isolation from other KT mechanisms offer businesses the potential for innovation and growth benefits and provide a potential for income for the PRO. But in general most benefit occurs when licensing is combined with other mechanisms to ensure that tacit knowledge and skills are also transferred giving the business an enhanced ability to commercialise and enhanced skills for the future. This means that most licensing takes place in the context of longer and deeper relationships between PROs and industry. Furthermore, as the analysis of PRO patents in Phase 1 of this study demonstrated (Appendix E) this KT mechanism is only suitable for certain science-based sectors, whereas other mechanisms have wider applicability.

The model demonstrates that all KT mechanisms provide value to PROs, industry and society and, taking volume and scale into account, it cannot be easily claimed that one mechanism results in more impact than any other. Therefore knowledge transfer policy needs to ensure that all mechanisms are facilitated and that no one mechanism is supported at the expense of another. Different types of PROs will make use of the mechanisms best suited to their institutional context and business environment.

3. Summary

The role of PROs in innovation

85. PROs are not simply 'suppliers' of technology or IP to industrial innovation processes. They provide problem-solving capabilities, skilled staff, access to specialist equipment, as well providing access to large pool of cumulative knowledge and technical know-how in a wide numbers of scientific and technical domains – any of which may stimulate new ideas for innovation or help support the development of pre-existing ideas.

86. To access this wide range of innovation inputs a number of different knowledge transfer mechanisms are used and valued by both industry and PROs. Individual companies often make use of several mechanisms, depending on the type of knowledge they wish to access and focus of their innovation activities.

87. The traditional channels of knowledge flow from (and across) the academic community remain key knowledge transfer mechanisms between academia and industry

    - Both PROs and industry view academic publications as the most important mechanism for transferring knowledge from PROs to industry
    - Both industry and PROs value informal interactions, with a slightly higher importance placed on them by industry than by PROs
    - These traditional mechanisms are not generally managed via any formal processes at the organisational level nor are they mediated though any sort of market transaction

88. A number of other knowledge transfer mechanisms are used, and viewed as relatively important, by many industry sectors – including consultancy, contract and collaborative R&D and accessing research skills via hiring and funding graduates and staff exchanges. They may be one-off interactions or form part of longer-term relationships.

89. Exploiting IP through formal transactions is generally considered to be of lesser importance to both industry and PROs. It is relatively more important to those sectors based on the life and physical sciences and engineering disciplines that underpin the science-based industries such as pharmaceuticals, electrical/electronics, chemical engineering and advanced materials than to other sectors. Nevertheless these sectors also make wide use of other knowledge transfer mechanisms to improve their knowledge base and develop long-term relationships with relevant academics and departments.

90. Different mechanisms transfer different types of knowledge – with publications and patents transferring codified knowledge and more interactive mechanisms, such as contract and collaborative R&D, transferring both codified and tacit knowledge.

91. Codified knowledge is often not sufficient for industry to make use of the outputs of PRO research and therefore businesses tend to make use of more than one KT mechanism. This is particularly the case when commercialising IP from PROs. The patented technology is usually at a very early stage and further input from researchers is required. Licensees often use other KT mechanisms – consultancy, contract and collaborative R&D or accessing skills (e.g. hiring PhDs) - to develop the technology further.

92. Therefore the different KT mechanisms are complementary rather than substitutes.

93. PRO patenting does not appear to compromise traditional academic activities and values, however KTOs can become a barrier to, rather than a facilitator of, knowledge transfer if they take an overly protective position on IP.

94. The different KT mechanisms are used by businesses to different extents to suit their particular needs and for particular purposes within their innovation activities, and therefore all the mechanisms can provide value to businesses, PROs and society. Each has its role in knowledge transfer.

Figure 6 Effects of KT mechanisms

KT Mechanism	Estimate of volume of new activity (per year)	Estimate of scale of the activity	What is transferred	Benefit to PRO	Benefit to industry (near-term)	Benefit to industry (long-term)	Benefit to society (long-term)
Informal interactions	**Unknown**	Short interactions	Tacit knowledge	95. New research ideas / opportunities 96. Extended innovation networks	97. Access to existing/ new knowledge 98. New ideas / opportunities 99. Enhanced innovation networks	100. Enhanced innovation networks	101. Spillovers
Publications	**500,000**	Relatively short interaction with research outputs & with no direct interaction with PRO	Codified knowledge	102. New knowledge 103. Enhanced reputation 104. Future funding	105. New knowledge 106. New ideas / opportunities	107. Potential for business growth	108. Increased stock of knowledge 109. Spillovers
Consultancy	**150,000**	Relatively short (few weeks) & low cost activity ~€5- 10k	Codified knowledge	110. Research income 111. New knowledge (contract R&D) 112. New research ideas 113. Reputation	114. Access to existing knowledge 115. Problem solving 116. Enhanced innovation networks	117. Enhanced innovation networks 118. Potential for business growth	119. Increased potential for innovation
Contract R&D	**50,000**	Medium-term interactions (several months) Costing <€50k	Codified and (some) tacit knowledge	120. Income 121. New knowledge 122. New research ideas 123. Reputation	124. New knowledge 125. New ideas / opportunities 126. Enhanced innovation networks 127. Skilled employees	128. Enhanced innovation networks 129. Potential for business growth	130. Increased stock of knowledge 131. Increased potential for innovation
Collaborative R&D	**20,000** (but around 75,000 in place at any one time)	Longer-term activity (3-5 years or longer) on a greater financial scale ~€100k-€2M	Codified and tacit knowledge	132. Research income 133. New knowledge 134. New research ideas 135. Reputation 136. PhDs & employment opportunities for	137. New knowledge 138. New know-how 139. New ideas / opportunities 140. Enhanced innovation networks 141. Skilled employees	142. Enhanced capabilities 143. Enhanced innovation networks 144. Potential for business growth	145. Increased stock of knowledge 146. Spillovers 147. Increased potential for innovation

KT Mechanism	Estimate of volume of new activity (per year)	Estimate of scale of the activity	What is transferred	Benefit to PRO	Benefit to industry (near-term)	Benefit to industry (long-term)	Benefit to society (long-term)
				PhDs			
Exploiting IP (patents / licences)	Patents: **10,000** Licences **15,000**	Limited interaction with academics (if no other mechanisms used in parallel) Variable financial scale	Codified knowledge	148. Income 149. Enhanced reputation	150. Access to new technology (providing new market opportunities)	151. Potential for business growth	152. Increased potential for innovation

153. The Role of Knowledge Transfer Offices

The first action of many European countries to develop the role of PROs in innovation was to enact laws or regulation, along the lines of the USA Bayh-Dole Act, to allocate ownership of intellectual property (IP) developed under public research funding to PROs and require PROs to be proactive in exploiting the knowledge they create. In some countries this also required the removal of legal restrictions that barred academics from engaging with industry or setting up companies.

Across Europe this process has taken place over a long period of time with, for example, the UK and Spain doing so in the early 1980s, Switzerland, France, and Belgium in the 1990s and Denmark, Germany, Norway, Slovenia, Hungary and Ireland in the 2000s. In some countries the law included a requirement for PROs to implement structures, processes and policies pro-actively to commercialise PRO-generated IP. In others the incentive to do so came later via additional laws or policies and, in some cases, public funding. As a result, across Europe, incorporating a 'third mission' for universities (and a second mission for research institutes) became standard for PROs.

In implementing the change in IP ownership, the early policies were heavily focused on 'technology transfer' from PROs in the form of the commercialisation of IP. In part this was a result of the dominance of the linear model of innovation but it was also due to the perceived success of the Bayh-Dole Act in the USA. These IP-focused policies led to the development of dedicated and centralised support within PROs for technology transfer in the form of *Technology Transfer Offices* (TTOs). However the evidence was mounting in the USA and Europe that, as only a few science-based sectors rely on patents to protect innovations (and companies in those sectors tend to be relatively well-connected to the top-performing PROs), only a small number of large research-intensive PROs with international reputations were able successfully to transfer their IP to industry and, furthermore, due to the early stage of the technologies, even fewer were able to achieve significant financial returns from their IP. The appearance of this evidence coincided with the development of a more complex and systemic picture of innovation. As a result, the emphasis of innovation policy relating to PROs started to change.

In many of the 'early adopter' countries, such as the UK and France, technology transfer policies have shifted towards 'knowledge transfer' policies with a broader definition of the purpose of knowledge transfer and the type of activities it entails. In these cases the commercialisation of IP has been recognised as just one tool in the knowledge transfer 'toolkit'. As already shown in Figure 4 the spectrum of knowledge transfer mechanisms is broad and this enables PROs, at least in theory, not only to interact with a wide range of industrial sectors and pubic bodies but also to involve a wide range of academic disciplines. Of course many of the knowledge transfer mechanisms have been in use for many years –the EC Framework Programme for example has been supporting collaborative R&D since 1984 and the UK LINK programme supporting collaborative R&D projects also started in the (late) 1980s – but the important point is that a wider range of knowledge transfer mechanisms are being recognised in innovation policy as key features of PRO-industry interactions.

Individual PROs in 'early adopter' countries have tended to follow this path of development, not only due to the shift in policy emphasis from technology transfer to knowledge transfer but also as a result of their own learning processes; a large number of the PROs case studied refer to their Technology Transfer Office (TTOs) as Knowledge Transfer Offices (KTOs), for example, as their role and remit has developed. Some KTO staff now refer to their role as *knowledge exchange* reflecting a greater acknowledgement of the two-way flow of knowledge between PROs and wider society. However it is important to note that while the policy language may have changed, the assessment of the success of knowledge transfer policies, as we will see later (section 208.1), is still heavily biased towards technology transfer – using metrics such as numbers of invention disclosures, patents, licences and licence income.

European KTOs are relatively young, and were created in response to law changes and policy requirements. Three-quarters of the European KTOs included in this study have been established since 2000 but some were established as far back as 1983. KTOs in New Member States have been created more recently, typically in 2004/05, but KTOs in Norway and Italy have also been established as recently as 2004/05. A 2007 study put the average age of European TTOs as just under 11 years, which suggests that our sample is fairly typical. A number of KTOs started life as industrial liaison offices and have taken on the wider technology transfer and then knowledge transfer role in response to policy changes.

1. Economic theory underpinning the KTO function

The IP exploitation role of TTOs and KTOs places them in a paradoxical position in relation to science, and research more generally, because the economic rationales for basic research and for patenting are opposite to each other.

The idea of 'market failure' leading to under-investment in research has been the principal rationale for state funding of R&D in the post-War period.[40] Of course, governments had been funding research long before the economics profession produced a reason. Arrow is generally credited with describing the three major sources of market failure, which – from a neo-classical perspective – make it useful for government to fund research

154. **Indivisibility**, because of the existence of minimum efficient scale
155. **Inappropriability** of the profit stream from research, leading to a divergence between public and private returns on investment. This results from two essential (and economically efficient) freedoms that scientific researchers have: namely to publish and to change jobs
156. **Uncertainty**, namely divergences in the riskiness of research respectively for private and public actors

[40] Ken Arrow , 'Economic Welfare and the Allocation of Resources for Invention,' in Richard Nelson (Ed.) *The Rate and Direction of Inventive Activity*, Princeton University Press, 1962; see also Richard Nelson, 'The simple economics of basic scientific research,' *Journal of Political Economy*, 67, 1959, 297-306

Arrow's argument was particularly relevant to more 'basic' (and, by implication, generally applicable) forms of knowledge because firms' inability to monopolise the results of such research meant they would be unlikely to invest in it. Instead the state invests on behalf of society. The spillovers that impede company investment in research provide the returns to society's investment. Hence the corollary of market failure is the need for science to be open. This openness enables both other scientists and 'users' of knowledge, such as businesses who wish to apply it to their innovation activities, to access it – something that is generally achieved through publication in the academic literature. Unlike many other goods, knowledge is not consumed in the process of being used, so society can get many spillovers from the use and re-use of a particular piece of knowledge.

In contrast the essential economic principle of the patenting system is that it offers the inventor, traditionally in industry, a bargain: temporary monopoly rights over an invention, in exchange for publishing details of that invention. The alternative would be a system of secrecy where knowledge that gives competitive advantage is kept out of the public domain entirely. The point of publishing patents is to allow others to use the information they contain, once the period of monopoly has finished (or during the protection period but at a price negotiated with the owner). The period of monopoly granted to the inventor represents a judgement about the balance between monopoly and subsequent spillovers that will be attractive to inventors while at the same time producing high social returns. Thus, while the purpose of scientific publication is to enable the use of new knowledge, patents are published in order (temporarily) to prevent its use.

Both the market failure rationale for publicly funding (at least basic) research and the system of patents assumes that once knowledge is openly available through publication (in journals or patents) limited effort is required for its transfer to other potential users.

The effects of university ownership on the rate of commercial application and the value of patents has been analysed based on European academic inventions patented at the EPO.[41] It found no statistically significant effects of university ownership of patents – when universities owned the patents, they were more likely to be licensed but this did not lead to greater commercial use. The implication is that legislation or policies intended to ensure PROs protect their invention may affect income distribution between companies and industry but has limited wider economic effects - that is it redistributes wealth between PROs and the private sector but does not necessarily create wealth. From the economic perspective, therefore, it does not matter overall whether universities or companies hold the IP rights to university inventions. The usefulness of KTOs, as far as IP is concerned, becomes a practical rather than a theoretical matter. If, in practice, they overcome systems failures, then they add value.

[41] GA Crespi, A Geuna and B Verspagen, *University IPRs and knowledge transfer. Is the IPR ownership model more efficient?*, SPRU Eectronic Working Papers Series No 154, Brighton: SPRU: 2006

However there are other important failures affecting economic performance. Relying on the neo-classical model of the firm, the market failure approach assumes away key deficiencies of real organisations, not least 'capability failures' such a lack of absorptive capacity for new knowledge.[42] Failures also exist at a higher level – such as failures in infrastructural provision and investment; 'transition failures'; lock-in failures; and institutional failures.[43] Furthermore, economists no longer simply view knowledge as readily codifiable and easily transferable information. Knowledge is a combination of codified, tacit, cumulative, and embodied in know-how and skills and therefore it is less easily transferred meaning that its transmission is not costless and requires 'purposeful interactions between economic agents'. This, therefore, aligns with the concept of knowledge, rather than simply technology, transfer and the use of a wider range of transfer mechanisms by PROs and industry.

The market and systemic failures justify state intervention not only through the funding of basic science, but more widely in ensuring that the Innovation System performs as a whole. The economic argument for Knowledge Transfer Offices then, is actually a *systemic one*: namely, that without them less PRO-generated knowledge would be exploited elsewhere in society, reducing overall welfare.

More specifically this argument for state intervention requires that KTOs serve to reduce the transaction costs of transferring uncertain and often un-codifiable knowledge from PROs to industry by: helping to bridge the cultural barriers between PRO researchers and industry; professionalising the interactions and relationships; and in the longer term, developing deep and sustainable innovation networks, encompassing PROs and businesses, as part of an inter-connected Innovation System.

[42] Erik Arnold and Ken Guy, 'Diffusion policies for IT: the way forward,' OECD/ICCP Expert group on the economic implications of Information Technologies, Paris: OECD, 1991

[43] See Keith Smith, *Systems Approaches to Innovation: Some Policy Issues*, TSER 3.1.1, Oslo: STEP Group 1996

1. The emergence and expansion of academic KTOs

Contemporary TTOs first emerged in the late-1970s in leading USA universities and affiliated medical schools, as departments within the university administration (e.g. at Harvard University, MIT and the UC system) or as independent licensing offices (e.g., at Stanford University). These offices took over technology transfer (i.e. IP exploitation) activities previously carried out by small administrative units, in some universities since the 1930s, or by independent intermediary organisations, most notably the New York based Research Corporation a leading broker that facilitated many licensing activities for USA universities since its establishment in 1912[44]. Following the introduction of the Bayh-Dole Act (in 1980), the universities' licensing increased sharply and the number of TTOs climbed from 25 in 1980, 200 in 1990 and to around 400-500 in 2009.[45,46] Similarly, the licensing income of universities rose from $183 million in 1991 to $2.4 billion in 2010.[47] In Europe the development of KTOs occurred somewhat later – the majority (59%) were established after 2000, 23% between 1990 and 1999 and 18% prior to 1990.[48]

One strand of the literature questions whether the Bayh-Dole Act was the root cause of the surge in university patenting in the USA through the 1980s and 1990s. Mowery and Sampat[49] argue rather that Bayh-Dole resulted from the desire of USA universities to patent their inventions – and they were already doing so (especially in molecular biology) before the Act was passed. It seems likely, that case law changes – especially the decision that "engineered molecules" were patentable, combined with measures by the USA government to strengthen international protection of intellectual property – were already responsible for a surge in patenting by USA universities.[50] This occurred primarily in biotechnology, where the bulk of the patents taken out are effectively for research tools.

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[44] David C. Mowery, Richard R. Nelson, Bhaven N. Sampat and Arvids A. Ziedonis, "The Effects of the Bayh-Dole Act on U.S. University Research and Technology Transfer," in: Lewis M. Branscomb, Fumio Kodama and Richard Florida, eds., *Industrializing Knowledge – University-Industry Linkages in Japan and the United States.* Cambridge: MIT Press, 1999, 269-306; and Richard G. Hamermersh, Josh Lerner and David Kiron, "Technology Transfer at U.S. Universities," Harvard Business School, Note 807-124, 2007 (January).

[45] Mowery, *et al.*, op. cit., 1999

[46] This figure is a lower bound estimate based on the number of US institutions that are members of AUTM the actual figure will be somewhat higher. Irene Abrams, Grace Leung, Ashley J. Stevens, "How are U.S. Technology Transfer Offices tasked and motivated—is it all about the money? " *Research Management Review*, Volume 17, Issue 1 Fall/Winter 2009),

[47] Mowery, *et al.*, op. cit., 1999 and *AUTM US Licensing Survey: FY 2010 – Survey Summary*

[48] Anthony Arundel, Franz Barjak, Nordine Es-Sadki, Tobias Heusing, Stefan Lilischkis, Pieter Perrett and Olga Samuel

Respondent Report of the Knowledge Transfer Study (data for 2010). European Knowledge Transfer Indicators Survey: Code of Practice Implementation Survey: Interviews with Firms Active in Four R&D Intensive Sectors. Report produced by empirica GmbH, Fachhochschule Nordwestschweiz and UNU-MERIT for the European Commission, DG Research and Innovation. February 2012

[49] David C. Mowery and Bhaven N, Sampat, "University patents and patent policy debates in the USA, 1925-1980', *Industrial and Corporate Change*, 10 (30), 2001, 99-119

[50] David C. Mowery, Richard R. Nelson, Bhaven N. Sampat and Arvids A. Ziedonis, "The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980," *Research Policy*, 30 (1), 2001, 99-120

Some argue that this – together with the resulting encroachment of the private sector on the 'scientific commons' is impeding rather than improving the rate and extent of scientific development and commercial application of the results of PRO research.[51]

The rise in university patenting in the USA appears to have tailed off from about the turn of the Millennium. Leydesdorff and Meyer argue that this has been driven by changes in university incentive systems, which have tended to refocus on research excellence (often expressed via ranking systems) and away from the previous push towards commercialisation (Figure 7).

Figure 7 University patenting 1978-2008 as a percentage of patenting at the USPO[52]

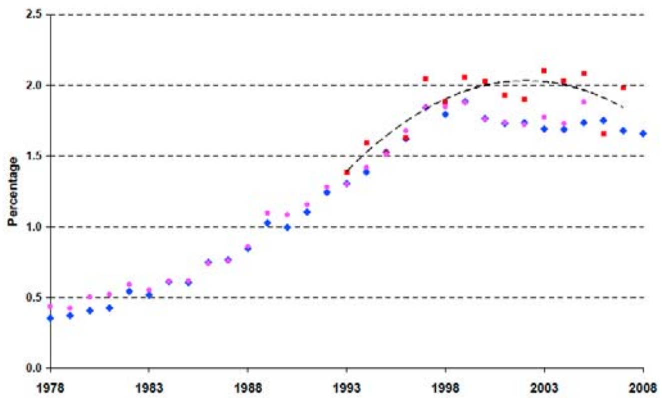


Figure 1: University patenting (1978-2008) as a percentage of patenting in the USPTO database. (Sources: ■ AUTM, 2008; ♦ online search at http://www.uspto.gov, 15 January 2009; ● Wong & Singh (2007).)

The organisation of knowledge transfer within European PROs is more recent than that of the USA and also followed a different path. Although the first European KTO was, reportedly, set up in 1973 at the KU Leuven,[53] the emergence of these offices set off in some European countries, including Spain and the UK, in the mid-late 1980s, intensified in the 1990s and continued through to the 2000s. A large number of KTOs were set up in the period 2000-2007 in several EU countries, including Germany, Italy and Poland.[54] European level associations, the ProTon Europe network and ASTP, have also been established to bring together and support KTOs and national professional associations via, for instance, exchange of experiences, development of skills and promotion of good practices. (N.B. the offices still tend to be referred to as TTOs in the USA.)

[51] Richard R. Nelson, "The market economy and the scientific commons," *Research Policy*, 33 (3), 2004, 455-472

[52] Loet Leydesdorff and Martin Meyer, *The decline of university patenting and the Bayh-Dole effect*, Scientometrics 83 (2), 2010, 355-362

[53] Aldo Geuna and Alessandro Muscio, *The Governance of University Knowledge Transfer*, SPRU, Electronic Working Paper Series, No. 173, Sussex University: SPRU, 2008

[54] ProTon Europe, *The ProTon Europe Fourth Annual Survey Report (fiscal year 2006),* ProTon Europe, 2008. Arundel and Catalina Bordoy, *Summary Report for Respondents: The ASTP Survey for Fiscal Year 2007.* Report produced for the Association of European Science and Technology Professionals, Maastricht: MERIT, 2008

The different patterns of TTO/KTO development, and the pace of development, in Europe are largely due to differences in national policies on PRO-industry relations as well as to variations in the fundamental characteristics of the research system and difference in the regulatory system for patents in individual countries. The emergence of TTOs/KTOs in France, for instance, was facilitated by the introduction of regulatory measures to accelerate innovation and to foster PRO-industry interactions between 1999 and 2006.[55] At the current time most European countries have Bayh-Dole style legislation and/or legislation establishing and in many cases, mandating, a third mission at PROs (examples are provided in Figure 8). Furthermore, in most European countries the legislation assigns the IP generated to the PRO. So-called 'professors' privilege' has largely been removed, although it remains in various forms in Sweden, Italy and Iceland (Figure 9).

[55] Laurent Bach and Patrick Llerena, "Indicators of higher-education institutes and public-research organizations technology transfer activities: insights from France," *Science and Public Policy*, 34(10), 2007, 709–721

Figure 8 Examples of law/regulatory changes enabling knowledge transfer at PROs

Country	Date of change	Description
UK	1983	1983 - IPR ownership passed to PROs 1993 - White Paper that started an era of policy focused on knowledge transfer role of PROs
Spain	1983 / 1986	1983 University Law and 1986 Spanish General Law on Patents, Inventions and Utility Models 157. Technology transfer recognised as a role of PROs 158. IPR ownership passed to PROs 159. 2008 Spanish Strategy fully recognises third mission for PROs
Switzerland	1992	1992 - IPR ownership passed to PROs
Wallonia (BE)	1997	The 1997 Decree of the Walloon Region: 160. IPR ownership passed to PROs
France	1999	Innovation law 1999: 161. Recognised knowledge transfer as a key mission of PROs and created strong incentives for engaging with industry and business creation
Netherlands	2000	2000 - national policy changes decentralised role of universities regarding knowledge transfer. 2004 - a Higher Education and Research Plan and a revised Science Budget – both documents introduced a number a policy measures for commercialising academic knowledge
Denmark	2000	Act on Inventions at Public Research Institutions – a law to regulate the ownership of inventions of university employees in Denmark and seeks to ensure that research results produced by means of public funds are utilised for the Danish society through commercial exploitation
Germany	2002	Changes to the Law on Employees' Inventions: 162. Abolished the system of 'Professors Privilege'
Norway	2003	Granted universities rights to commercially exploit IP developed by their faculties, while also mandating that the universities facilitate research-based innovation through the licensing of technology and the formation of new enterprises. It required universities to more actively facilitate research-based innovation
Ireland	2004	A number of Codes of Practice that established guidelines for IPR 163. The first, in 2004, addressed the management of IP from publicly funded research 164. The second, published in 2005, addressed the management and commercialisation of researcher from public private collaborative research.
Hungary	2004	The Act CXXXIV of 2004 on Research, development and technological innovation: 165. PROs required to establish IPR management systems
Slovenia	2006	Research and Development Act No 22/2006: 166. IPR ownership passed to PROs

Technopolis: KTO case studies

Figure 9 Ownership of IPR in European Universities and other PROs

	Universities			Non-University PROs		
Country	Institution	Inventor	Government	Institution	Inventor	Government
Austria	X			X		
Belgium	X			X		
Denmark	X			X		
Finland	X			X		
France	X			X		
Germany	X			X		
Iceland		X		X		
Ireland	X			X		
Italy	x	X		x	X	
Netherlands	X			X		
Norway	X			X		
Poland	X			X		
Spain	X			X		
Sweden		X		X		
Switzerland	X	x		X		
United Kingdom	X					

X = Legal basis or most common practice, x = allowed by law/rule, but less common. Source[56] (updated by Technopolis)

1. PRO knowledge transfer strategies

1. National legislation/regulation to support knowledge transfer

The 19 European PROs studied are located in countries that have amended their national laws or regulations to enable knowledge transfer between PROs and industry. In most cases the laws and regulations relate specifically to IP ownership while some also state that there is a requirement for PROs to undertake activities to commercialise the IP and/or engage in knowledge transfer. In many cases the laws are supplemented by policies that provide more detail of the expected mission or PROs and any relevant funding programmes. These legal and regulatory changes have led directly to the establishment of TTOs and development of institutional policies for IP ownership and management. In most cases the initial policy focus was on IP exploitation or 'technology transfer' was expanded over time into new laws, regulations or national policies that defined a wider third mission i.e. that of knowledge transfer to industry and society rather than just IP exploitation and the subsequent development, in many but not all cases, of TTOs into KTOs.

However other studies show that a number of European Member States are lagging and have yet to implement national laws, regulations and/or policies for knowledge transfer (Figure 10). While the majority of these are New Member States the list also includes the older Member States of Greece and Portugal.

[56] *Turning Science into Business: Patenting and Licensing at Public Research Organisations*, Paris: OECD, 2003 (modified to account for the subsequent abolition of professor's privilege in Finland)

Figure 10 European countries with legal/ regulatory /policies in place to promote KT

Countries WITH legal/regulatory/polices to promote KT as a strategic mission of a PRO (n=19 : 70%)		Countries WITHOUT legal/regulatory/polices to promote KT as a strategic mission of a PRO (n=8 : 30%)
Austria	Ireland	Bulgaria
Belgium	Italy	Greece
Cyprus	Luxembourg	Latvia
Czech Republic	Netherlands	Lithuania
Denmark	Romania	Malta
Estonia	Slovenia	Poland
Finland	Spain	Portugal
France	Sweden	Slovakia
Germany	United Kingdom	
Hungary		

Source: ERAC[57] (orange denotes countries in the study sample)

2. *Institutional strategies for knowledge transfer*

The PROs studied include a third mission in their institutional strategies and address it in a broad sense as knowledge transfer rather than technology transfer. The third mission goes under several names including: *knowledge transfer; knowledge valorisation; business and enterprise; and 'wider engagement with society.* While the strategies refer to the role of IP management and commercialisation in the third mission they also include other aspects of knowledge transfer such as consultancy, collaborative and contract research, the development of incubators and science parks as well as building an entrepreneurial culture among staff and students through, for example, education (students), training and awareness raising (staff) and specific activities such as business plan competitions etc. This tells us that PROs do not regard their knowledge transfer role as being solely about IP commercialisation and is, therefore, much more in line with the innovation systems model, with PROs taking a multifaceted approach to industrial engagement to facilitate knowledge flows.

Over and above the need to develop a dedicated KTO resource to professionalise the knowledge transfer interface and manage and commercialise IP, PRO strategies do not make statements about the use of particular KT mechanisms, that is they do not specify the use of particular mechanisms over and above other mechanisms nor do they detail specific mechanisms for particular sectors. However PROs recognise that different sectors work in different ways and often employ sector specialists who understand sectoral needs, business models and working methods. The KTOs studied recognise that certain sectors are more likely to engage in IP licensing and employ specialists accordingly (e.g. IP specialists with a knowledge of the pharmaceutical, electronics or telecommunications sectors for example). The general view from KTO staff is that interactions are dealt with on a case-by-case basis and as long as the under-pinning policies (such as for IP ownership) are in place, the KTO staff will aim to find the most appropriate mechanisms for each academic-industry interaction.

[57] ERAC, op. cit (2011)

Therefore, there does not appear to be any significant trading off amongst KT mechanisms at an institutional level, leaving KTOs and academic staff to make decisions about mechanisms. However where targets are in place for specific KTO /PRO outputs such as revenue generation or, for example, incubator/science park tenancies, these can be expected to influence individual decisions.

The PROs studied have institutional policies in place with regard to IP ownership and the allocation of IP income between the individual inventor (the researcher), his/her research group or department and the central university/PRO and the KTO. (Other surveys show that most European PROs have such IP ownership policies).[58] While the actual allocations vary it is quite typical to find a model such that the KTO costs are reimbursed, followed by a roughly three-way split between the inventors, research group/department and the university. In some countries the proportion allocated to the individual inventor is defined in the relevant IP legislation but in others it is defined at the institutional level. Only two countries in Europe formally retain ‘professor privilege’ (that is professor ownership of IP) - Sweden and Italy. However this does not mean that the KTOs do not exist nor that the PROs do not provide support to IP commercialisation. It is recognised that most academics do not have time, resources, skills or, in some cases the inclination, to commercialise their research outputs, and therefore professional support and encouragement to commercialise is still required. In Italy the pendulum seems to be swinging back towards institutional ownership of IP; professor privilege was brought in to incentivise commercialisation among academics in 2001 but more recent regulatory changes in 2005, have returned IP from publicly funded research (but other not from research funded from other sources) to the institution to enable a more centralised approach to commercialisation.

The majority of PROs studied have dedicated KTOs staffed by professional knowledge transfer staff – typically with experience of both the academic and business environment plus specific skills in project management, sector expertise, relationship management and marketing and communications. Whether a KTO employs legal expertise or outsources this role is largely dependent on the scale of the IP commercialisation undertaken. A smaller number of those studied do not have a dedicated KTO but have a more embedded structure for the support of knowledge transfer activities (see section 181.1)

In terms of the geographical focus of knowledge transfer activities, PRO strategies are dependent on the scale and quality of the research undertaken and reputation of the individual PRO. Large internationally renowned research intensive PROs have an international market for their knowledge and will regularly engage with large multi-national corporations and, in some cases, attract such businesses to their location. This does not mean that they have no national or regional focus to their KT activities, as these PROs often have a higher number of spin-outs and may establish incubators or science parks to house them and attract other high-tech businesses to the area – such as high-tech clusters around the universities of Oxford and Cambridge. Meanwhile, top-performing national PROs will work with businesses on a national and possibly local level, while smaller and more regionally focused PROs will tend to support the businesses in their region and the local SME base. The University of Debrecen has, for example conducted a market analysis of the businesses in its region to better understand their needs and develop their knowledge transfer activities and processes accordingly.

[58] Arundel et al. *op.cit* (2012)

The University of Hertfordshire, as an ex-technical college, has a long tradition of serving its local industrial base in aerospace and pharmaceuticals, and more recently in ITC, and targets its knowledge transfer activities to these businesses the majority of whom are SMEs. Therefore not all knowledge transfer strategies are, or should be, the same. The target 'audience' for knowledge transfer will be highly dependent on the type of PRO and its national and regional industrial context.

2. Remit and role of KTOs

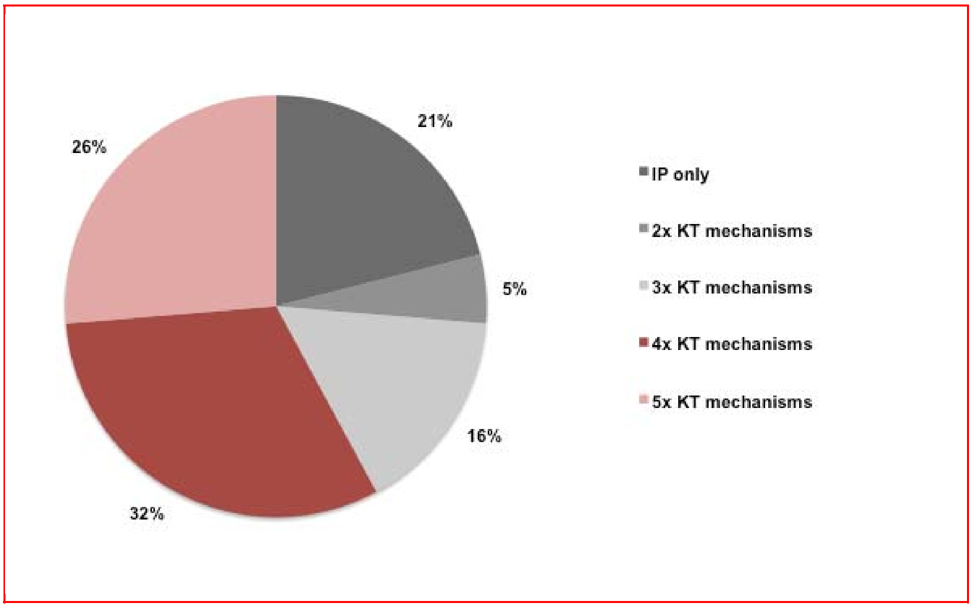
The breadth of PRO knowledge transfer activities is reflected in wide ranging roles and remits of KTOs. The remit of KTOs has been expanding with only a small proportion in the sample focused on IP only, with most having a remit that includes a number of KT mechanisms. Only 25% of the European KTOs studied are responsible for just IP (Figure 11). These include just two universities (Lund and NTSU) and two research institutes (CNRS and Fraunhofer). One is a large Swedish university and therefore supporting IP exploitation under the professor privilege model and the other is a medium-sized specialist science and technology university. The research institutes have a different model for KT that matches the organisational structure of these large distributed research organisations. IP exploitation is managed by a centralised function so benefiting from economies of scale and access to specialist expertise, while other KT mechanisms are the responsibility of the distributed research institutes so keeping the more collaborative activities closer to the individual researchers.

More than half of the KTOs are responsible for four or five KT mechanisms. Although it should be noted that in the smaller and/or more regionally focused universities (Sussex, UTC, Hertfordshire) the responsibility for knowledge transfer is spread much more widely across the institution rather than the sole responsibility of a KTO. Other studies and surveys (such as the ASTP Survey for 2008)[59] reinforce the findings that KTOs with wide remits are fairly commonplace. By contrast the USA KTOs are typically only responsible for IP exploitation.

Figure 12 provides more detail on the features of PROs and the remit of their KTOs. Apart from the USA examples, the remit does tend to align with the type of PRO in terms of its quality/ research-intensity ranking, age or relative size of the KTO. Size would appear to have some correspondence to the breadth of remit with larger universities having a smaller KTO remit – either IP exploitation alone or IP exploitation one or two other KT mechanisms. This may well be a consequence of their size, as larger and more research-intensive universities will generate more IP, not only leading to a larger IP management task but also creating greater opportunities for licensing and spin-outs and therefore a requirement for a dedicated IP team. The two research institute systems studied, CNRS and Fraunhofer, are significant in scale (with 35,000 and 17,000 staff respectively) with geographically dispersed staff. Their KTOs have been established to focus on the commercialisation of IP as might be expected from such large research-only institutions.

[59] Anthony Arundel and Catalina Bordoy, *Summary respondent report: ASTP survey for fiscal year 2008*, UNU-MERIT report for the Association of European Science and Technology Transfer Professionals, January 2010

Figure 11 Responsibilities of KTOs in the sample



Source: Technopolis case studies

Smaller more regionally focused universities with a greater focus on education than research, such as UTC and the University of Hertsfordshire, tend to have a much wider knowledge transfer remit, integrating the management of research and education focused knowledge transfer These PROs make less of a distinction between research and education focused engagement activities and so enable businesses to easily access training and continual professional development as well as research skills and knowledge. In some ways, for these PROS, the knowledge transfer mission is less of a novelty, as their role has traditionally focused on the needs of local businesses and the expansion of their knowledge transfer activities has required less of a cultural shift than for the research-intensive institutions.

The relative proportion of IP activity within the KTOs varies, as would be expected, depending on the number of knowledge transfer mechanisms covered, but among those responsible for all mechanisms the proportion is at the 25-35% level. The PROs report that where they do engage in IP commercialisation it is predominantly with the disciplines and sectors already identified as appropriate for IP transfers - life and physical sciences and engineering, pharmaceuticals, electronics and in some cases materials. The PROs also report that the IP-based interactions tend to be with a relatively small group of academics and with businesses already known to the academics (as reported in reported section 80.1 and as noted by MIT for example).

Along with a smaller focus on IP comes a different over-arching function for the KTO – it is less about generating income for the PRO and more about wider dissemination of PRO research outputs for social benefit. Examples from our sample describe the purpose of the KTO as:

167. University of Barcelona: "..making available scientific/technical capabilities, research results and know-how generated within the University of Barcelona Group to companies, institutions and society in general"

168. University of Tuebingen: "….supporting the use of university research results for the public benefit… the main objective of the university in terms of technology transfer is, simply, to enable the successful transfer of technology for the benefit of the wider society"

169. KTH Zurich: "transferring knowledge to the private sector and society at large is the primary concern"

170. MIT: "The Technology Licensing Office... *primary objective* being to move the results of research into commercial and societal use and by doing so contribute to economic and social development i.e. the goal is to help new technologies get to market and be put to productive use."

Recent research in the USA reports similar findings, with the key drivers of TTOs being translating the results of research and providing a service for faculty. By contrast very few USA TTOs were driven by revenue maximisation.[60] This is further demonstrated by the fact that the majority of TTOs in the USA are not self-financing (see section 205.3). However, somewhat in contradiction to the case studies, recent search in Europe shows that income generation *is* a key driver of KTOs (reported by 60% of those surveyed) in parallel to generating possibilities for collaboration in research and teaching (59%), followed by promoting the diffusion of science and technology (45%). This suggests that in Europe at least there is some tension between generating income and diffusing research. While protecting and exploiting IP is not inherently at odds with diffusion – IP protection is essential in some fields and sectors – generating, and particularly maximising, income from IP might reduce knowledge diffusion by either deterring potential licensees or limiting the extent of diffusion through the granting of exclusive licences.

The wider knowledge transfer objective of PROs means that the KTO is just one of many actors involved. Knowledge transfer is, at its heart, the interaction of individual academics (or small groups of academics) with a person (or small group of people) in a business – this is where the actual process of transfer and exchange happens. Even where IP is involved it is common for further interactions between the academic inventor and the businesses to take place. Therefore the role of the KTO, in the main, is to support the KT interactions of researchers. This is not to say that the role of a centralised, dedicated and professional KTO is not important, but that its role should be to *maximise* the volume and impact of KT activities carried out by academic staff.

In support of PROs' knowledge transfer objectives a typical KTO conducts the following activities:

171. Marketing and communications

172. Communicate to industry the knowledge and skills existing within PROs

173. Conduct research to understand business needs, seek new opportunities for knowledge transfer and pro-actively promote interactions between industry and the PRO

[60] Abrams et al. *op. cit* (2009)

174. Identifying opportunities for knowledge transfer (including IP exploitation) through their awareness of the collaborative/contract R&D and consultancy undertaken by the PRO

175. Ensuring professional and efficient practical interactions with businesses

176. Develop efficient processes within the PRO (for writing and signing contracts, delivery of outputs, IP management etc.)

177. Relationship management (with key industrial contacts, new enquiries and with academics)

178. Project management

179. Support academics in their business interactions

180. Disseminate good practice within PRO

181. Contributing to the development of an entrepreneurial skills base within the PRO through training, publishing guidelines etc.

Definitions used in Figure 12 below

PRO type	Description	PRO size	Description
1	Top European universities (ranked in top 50 in THES 2011/12); in innovation leader, or top performing countries (Pro-INNO definition)	**S**	Less than 1,500 academic staff
2	TOP non-university research performers ; in innovation leader, or top performing countries (Pro-INNO definition)	**M**	1,501 to 3,999 academic staff
3	Medium-high ranking universities; in innovation leader, top performing countries or follower country (Pro-INNO definition)	**L**	More than 4,000 academic staff
4	Less-research intensive universities but with strong /interesting KTO function /model		
5	PROs in new member states / peripheral regions		
6	PROs in USA		

KEY:

Large KTO (with respect to staff numbers): >1% of academic staff	N.B. The three PROs below at the bottom of the table do not have standalone KTOs
High-quality, research-intensive PRO (based on THES 2011/2012ranking)	
USA PRO	
KTO established (in some form) before 2000	

Figure 12 PROs and the breadth of activity in terms of KT mechanisms

PRO type	PRO	Size of PRO	Size of TTO	Age of KTO*	Relative scale of IP activity to other KT mechanisms (estimated)	IP exploitation	Contract R&D / consultancy	Collab R&D / partnerships	Promoting/ informal partnerships	Promoting access to skills
6	Colorado University (USA)	L	20	2002	All IP	Y	N	N	N	N
6	University of North Carolina (USA)	M	12	1995	All IP	Y	N	N	N	N
6	MIT (USA)	M	34	1983	All IP	Y	N	N	N	N
3	Norwegian University of Science and Technology	M	18	2004	All IP	Y	N	N	N	N
1	Lund University (SE)	M	20	1995	-	Y	N	N	N	N
2	Fraunhofer (DE)	L	18	1999	-	Y	N	N	N	N
2	CNRS (FR)	L	47	1992	-	Y	N	N	N	N
1	University of Oxford (UK)	L	74	1988	IP: other 60:40	Y	Y	N	N	N
1	University of Aarhus (DK)	L	15	2000/ 2003	IP: other 50:50	Y	N	Y	Y	N
3	University of Tuebingen (DE)	L	6	1980s/ 2002	IP: other 80:20	Y	Y	N	Y	N
3	University of Milan (IT)	M	6	2005	-	Y	N	Y	Y	N
3	University of Barcelona (ES)	L	52 (46 FTE)	1983	IP:other 25:75	Y	Y	Y	Y	N
3	University Libre Bruxelles (BE)	M	19	1990s/ 2003	IP:other 33:67	Y	Y	Y	Y	N
3	University College Dublin (IE)	M	10.5 FTEs	2003	IP:other 40:60	Y	N	Y	Y	Y
4	University of Debrecen (HG)	S	11	2006	Limited IP	Y	Y	Y	Y	N
4	Mayasark University (CZ)	M	8 FTEs	2005	-	Y	Y	Y	Y	Y
1	Delft University of Technology (NL)	M	35	2000/ 2004	IP:other 20:80	Y	Y	Y	Y	Y
1	ETH Zurich (CH)	S	14	1995/ 2005	IP:other 35:65	Y	Y	Y	Y	Y
4	Maribor University (SI)	-	Not know n	2005	-	Y	Y	Y	Y	Y
1	University of Sussex (UK)	S	n/a	2004/ 2008	Limited IP	Y	Y	Y	N	Y
4	Université de Technologie de Compiègne (FR)	-	n/a	1987/ 2006	Limited IP	Y	Y	Y	N	Y
4	University of Hertfordshire (UK)	S	n/a	n/a	Limited IP	Y	Y	Y	Y	Y

* denotes a KTO that existed in an original form (1st date) and was modified into its current form (2nd date).
A blank denotes where the information was not available

1. Organisational structures and governance

1. Organisational structure

KTOs can be organised in three distinct ways:

182. Internal units or specialised departments within PROs

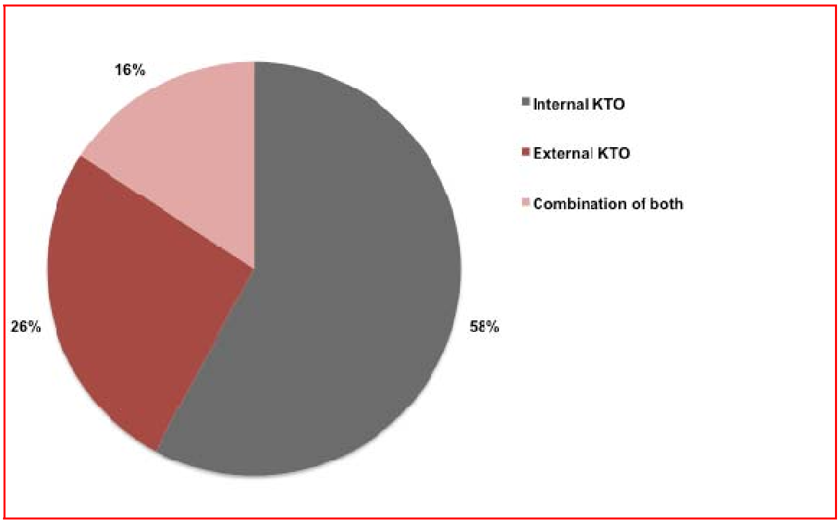
183. External subsidiary organisations working outside of a PRO which are usually wholly owned by the PRO,

184. Public or private, independent KTO intermediaries serving more than one PRO

All three organisational models exist in Europe with the latter 'pooled' services model being most common in countries where national policy has encouraged or actively supported such an approach, usually at the regional level, as in Germany, Finland and Denmark.

None of the PROs case studied was part of a multi-PRO KTO. All structured their KTO as either an internal support function or an external, but wholly owned, subsidiary. The choice between the two structures is largely due to national and institutional contextual factors. External KTOs are established for example to avoid rigid and/or bureaucratic PRO administrative structures, to separate a potentially profit-making business from a public institution, to provide the KTO with a higher degree of autonomy to act, or to separate the potential liabilities associated with IP and spin-outs. In some countries there have also been tax advantages for external KTOs. In the sample, 58% of European KTOs were internal to the PRO, 26% external and 16% a combination of both – where, in the case of Lund and UTC for example, the function of investing in proof-of-concept or spin-outs, or the consultancy function is managed by an external (but wholly owned) body and the rest of the knowledge transfer activity is managed internally.

Figure 13 Organisational structures of KTOs



Source: Technopolis

One of the key issues is the ability for KTOs to respond and interact with businesses quickly and efficiently. This often led to the very early KTOs, such as at the Universities of Oxford and Barcelona, establishing external KTOs outside the university bureaucracy. This enabled these KTOs, that were predominantly focused on IP exploitation, to act quickly and make deals with businesses. However, this structure also led to criticism from some academics that the KTO, by avoiding internal processes, was not acting in the best interests of PRO as a whole.

Most KTOs in the sample are organised as internal functions within the PRO with a fair degree of autonomy with respect to decision-making, which may include delegated authority to sign contracts or a very close working relationship with the contracts and/or research support function. In PROs, particularly in New Member States, where only the PRO president or rector can sign contracts, causing significant delays for IP agreements, contract R&D etc., an external KTO model may be chosen. It is interesting to note that the external organisational model is less common in the USA; the three USA KTOs (which only focus on IP exploitation) are managed as internal functions but with considerable autonomy; at MIT and the University of North Carolina for example the head of the KTO can sign licence agreements, and the University of Colorado the head of the KTO reports directly to the Vice-President of the university.

Fundamentally KTOs need to engage effectively with the researchers as well as businesses, as it is the researchers who ultimately interact with businesses and therefore operational models and staff need to be able to work in both directions – inwards towards the PRO and outwards to industry.

The Technical University of Delft has a matrix organisational model. Its KTO is structured as a 'hub and spokes' with an external central KTO team plus (internal) departmental KT staff employed and managed within the departmental structure. This model benefits from the economies of scale for specific KT activities (strategy, marketing and communications etc.) and professional expertise (IP management, contract negotiation, spin-out creation etc.) and the proximity of KTO staff to researchers. Other PROs have a similar approach: the University of Hertfordshire has a similar model but with both the central and departmental teams being fully within the university employment and administrative structures; and CNRS, as a very large research organisation has a central KTO (in this case focused only on IP) that works in partnership with 20 regional 'Partnership and Knowledge Transfer Services' and with knowledge transfer correspondents in each of its ten large Research Institutes. Empirical studies suggest that the matrix model is most effective as it balances access to centralised specialist expertise in knowledge transfer (in the KTO) with enabling direct contact between researchers and industry.[61]

Interestingly in the USA, where most TTOs are focused on the exploitation of IP, the majority of TTOs appear to be organised as internal functions.[62]

[61] Koenraad Debackere and Reinhilde Veugelers, *The role of academic Technology Transfer Organisations in improving Industry-Science links, Research Policy,* 34 (3), 2005, 321-342

[62] Abrams et al. *op. cit* (2009) (86% of TTOs surveyed were organised as internal functions)

The literature also suggests that the KTOs' organisational structure and capabilities are key determinants of KT effectiveness as these can drive, or obstruct, the effective functioning of TTOs. Empirical studies on the performance of KTOs found that the specific characteristics of the organisation of knowledge transfer, that is, information-processing and coordination capabilities and incentive alignment capacity, have shaped technology transfer activities and also account for differences in the development and performance of KTOs.[63] Important issues include:

185. An appropriate balance between centralisation and decentralisation within academia, including the creation of a dedicated transfer unit that brings together the specialised resources needed to do the job

186. The design of appropriate incentive structures for academic research groups

187. The implementation of appropriate decision and monitoring processes within the KTO

188. A transparent and well-articulated IPR regime

In a number of the PRO studied the organisational structures have changed:

189. The University of Sussex closed its external TTO (focused solely on IP) and brought the function back in house to align it more closely with wider knowledge transfer activities. It was felt that, as industry is best placed in terms of skills and resources to commercialise technology, an IP-focused and income driven TTO was not the best model to facilitate a more open and collaborative interaction with business

190. The Norwegian University for Science and Technology, with an external KTO, has been considering whether an internal KTO function, more integrated with the university, might be a more appropriate structure for the future.

191. The University of Aarhus recently considered changing to an external KTO where parts of the TTO should be incorporated as a public limited company. Such a move, it was thought, might facilitate the establishment of a more dynamic and outward looking environment. However, a recent study on reform at Aarhus came to no strong conclusions as to the need for organisational change[64] – suggesting that it is far more important to identify the right people and to manage them well, rather than worry about the organisational form itself. The report highlighted that some of the best technology transfer environments in the world operate as integrated units within university administrative structures.

192. The Eberhard Karls Universität Tübingen (EKUT), while part of a German regional multi-PRO independent KTO set up to undertake commercialisation services for all universities in its remit, also set up its own KTO. It made the decision that knowledge transfer was so important that it needed to be conducted internally, with direct links to the university (through physical location, personal relationships and governance structure). A number of German universities have taken this route (i.e. establishing their own local KTO) and they are considered to be more successful than those relying on an independent multi-PRO KTO function.

[63] Janet Bercovitz, Maryann Feldman, Irwin Feller and Richard Burton, *Organizational Structure as a Determinant of Academic Patent and Licensing Behavior: An Exploratory Study of Duke, Johns Hopkins, and Pennsylvania State Universities*, Journal of Technology Transfer, 26 (1-2), 2001, 21-35

[64] Sachi Hatakenaka and Quentin Thompson, *Aarhus University: Reform Review – Final Report*, University of Aarhus, 2010

These changes in organisational structure reflect the shift in emphasis from technology to knowledge transfer, and therefore less of a focus on the process of IP management and exploitation and more of a focus on developing relationships with academics and industry - so requiring the KTO itself to work more closely with its research community.

The PROs cases studied identified the advantages and disadvantages of the internal and external models for KTOs (Figure 14). The issues all centre on a balance between a close alignment of purpose between the KTO and the wider PRO and the autonomy and flexibility to act. The former is more easily achieved within an internal KTO, while the latter, historically was thought to be more easily achieved through an external KTO. However, the sample shows that a degree of autonomy for the PRO can be achieved within the PRO and so perhaps the external model will be less favoured as the knowledge transfer mission becomes more embedded within the PRO – in terms of institutional strategy and mission, organisation and management and physical location - and as PROs modernise and reduce bureaucracy. Nevertheless, the final decision as to the design, role and operation of a KTO lies with the PRO, in order to develop a solution to meet the requirements of its institutional and geographic context.

Figure 14 Advantages and disadvantages of KTO organisational structure

	INTERNAL KTO	EXTERNAL KTO
Advantages	193. The KTO staff are employed by the PRO, and therefore fundamentally aligned with the PRO's mission. This provides the KTO and its staff greater legitimacy, from the point of view of academic staff as they are part of the same system 194. Being closely aligned with the research mission and research administrative function enables the KTO to be more aware of all the research contracts that are conducted within the PRO which aids the process of indentifying research outputs, including IP, with application potential 195. Physical and intellectual proximity to researchers	196. Greater autonomy and freedom and flexibility to act as they see fit - and act quickly 197. A business culture more akin to its business clients, as a result of its responsibility (to greater and lesser degrees depending on the exact model) for its own strategy, operations and finances 198. Clearly demonstrates to industry the PRO's intention to engage in knowledge transfer 199. More potential for economies of scale in the provision of specialist services
Disadvantages	200. The potential to be caught up in PRO administrative bureaucracy and so reducing its ability to respond to industrial needs quickly and flexibly 201. (In some cases) restrictions on employment salaries and terms which make it difficult to recruit professional KTO staff	202. Creates a boundary between the KTO and the wider PRO 203. This can lead to a reduced legitimacy with academic staff, discouraging academics from engaging with the KTO as there is a concern that it does not represent the PRO's or academics' best interests. 204. The establishment of a culture that places knowledge transfer outside of every day duties and activities of the PRO and individual academics – potentially decreasing the level of

	INTERNAL KTO	EXTERNAL KTO
		knowledge transfer activity 205. If physically separated from the PRO these disadvantages can be exaggerated

1. *Governance*

The governance of KTOs, where it sits in the PRO management structure and to whom it is responsible reflects its importance within the institution and its alignment with, or distance from, other key missions and activities.

The early KTOs, focused on IP exploitation, were seen not only as a means to conduct technology transfer but also as revenue generators and, as a result, were often positioned within the finance structures of PROs. However, among the sample this no longer seems to be the standard approach to KTO governance. All but one of the KTOs studied have taken the view that the transfer of knowledge generated from research is best managed as part of the PRO's research mission. The senior member of staff with responsibility for the KTO and the knowledge transfer mission more generally, is usually the Vice-Rector (or equivalent) for Research or, increasingly, a dedicated Vice-Rector with responsibility for innovation/ enterprise/knowledge transfer (the title varies somewhat institution to institution) who works closely with the Vice-Rector for Research - for example: University College Dublin has a Vice President for Innovation; the University of Barcelona has a Vice-Rector for Innovation and Knowledge Transfer; the Norwegian University for Science and Technology has a Vice-Rector for Innovation and External Relations and University Libre Bruxelles has a Vice Rector for Institutional Relations and the Transfer of Knowledge. In a few cases the KTO reports directly to the President/ Rector's office. Only one of the KTOs studied is governed via a financial management route (the KTO at the University of Oxford) but even so, this KTO has close day-to-day working relationships with the Vice-Chancellor for Research and the research support administrative function. This positioning of KTOs either within, or close to, the governance structures for research reflects the alignment of KTOs with the research mission and their broad remit to transfer knowledge for societal benefit, rather than an overtly financial role (as described in section 166.2).

Some of the regional PROs in the sample align their knowledge transfer function with both research and teaching, reflecting a combination of their lower research-intensity and a strong focus on education and training in support of local businesses. They tend to make less of a distinction between research and education when supporting local businesses – aiming to find the best solution to company needs as appropriate. Often these PROs have a long tradition of business engagement (often longer than the more research-intensive PROs) as their role has been to meet the needs of their local business and social communities.

At an operational level the KTOs have a close working relationship with the internal research support function - that is the staff that support the bidding, management and administration of research grants and projects.

It is also common for KTOs, especially those established as external bodies, also to report to committees or boards. The role of the boards and committees varies from strategic to operational as does their composition – with some composed solely of PRO staff (which may include senior management staff only or include practising researchers) and others including representatives from industry (e.g. Lund, NTNU, Milan)– although industry representation is unusual. Some KTOs also act in an advisory role, providing advice on knowledge transfer strategy to senior management.

Despite the variation in governance models in an operational sense (committees, boards etc.), as is to be expected for the wide range of PRO institutions and national contexts across Europe, there is a clearly consistent view, within PROs, that knowledge transfer is not a separate mission but one that is closely aligned with their core missions – most commonly with research, but also with education.

2. Resources

The majority of KTOs are small relative to the size of the PRO. The case studied KTOs have between 6 and 74 staff; on average this represents around 0.7% of total academic staff (**Figure 12**). ETH Zurich is an outlier as a small university with a relatively large KTO. Larger surveys show that European KTOs are slightly smaller than their counterparts in the USA. In Europe the average size of a KTO is 8 staff (median 6) and in the USA the average size is 12 staff (median 7).[65]

The small KTO size limits the ability to act but also reinforces their role as supporting the knowledge transfer activity of the researchers themselves. Nevertheless most KTOs feel that there is more they can do, as at present they work mostly with academics that are willing to engage and/or already have a track record of industrial interactions, and they would be able to increase knowledge transfer activities with more resources.

KTOs employ highly qualified staff with experience in both academia (often holding PhDs) and businesses, enabling them to understand and bridge the very different academic and business cultures. Depending on the size of the KTO they may be supported by professional IP experts and marketing and communications staff. While knowledge transfer as a profession has been developing and growing over recent years there is a general concern among KTOs as to their ability to attract and recruit suitably qualified staff. This is in part due to the very specific experience required but also, due to PRO and/or national restrictions on salaries and reward for what are considered to be administrative roles.

3. Costs and benefits of operating KTOs

The costs of operating a KTO or TTO consist primarily of staff costs (salaries and other compensation, accommodation, equipment, etc.) and IP protection costs. In all but the largest and most active PROs, staff costs are larger than patent costs. In the USA TTOs report staff and patents costs as almost equal. A reasonably large KTO of 20 staff costs €2-2.5 million to operate, plus there are the costs relating to the inputs of individual researchers.

Early technology transfer policy expected TTOs to not only act as mechanisms for innovation through IP exploitation but also as a revenue generator for PROs. The experience of the last 20 years, in the USA and Europe, has demonstrated that **most PROs do not generate significant revenue from IP**. Studies consistently show that a small number of PROs account for a large share of IP income:

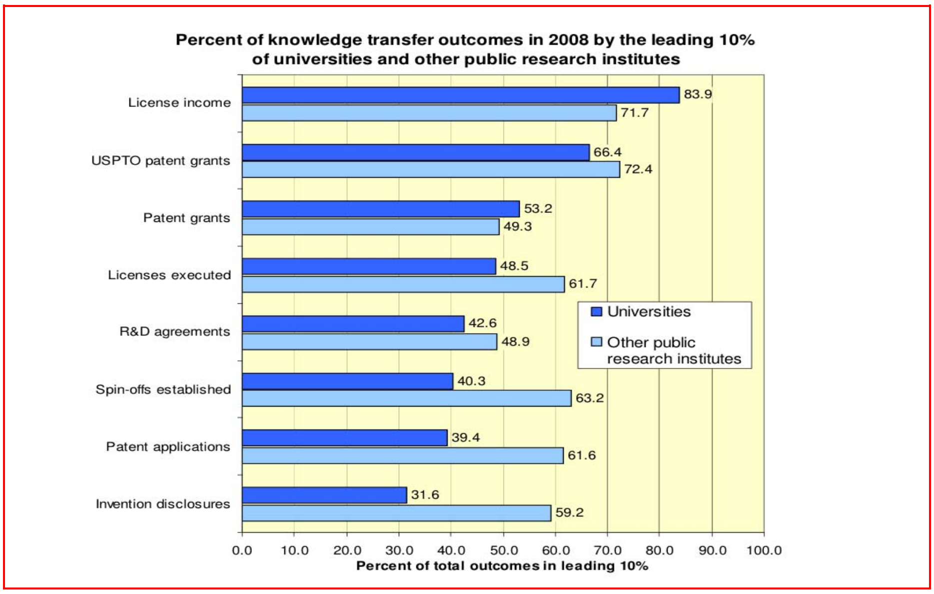
[65] Abrams et al. *op. cit* (2009); Arundel et al. *op.cit* (2012)

206. The 2010 AUTM survey of 183 respondents from research universities, hospitals/medical centers and research institutes in the USA reported that the total licensing income was $2.4 billion.[66] However the distribution was highly skewed with the **5% of the universities accounting for 41% of the income,** with these PROs receiving in the range of $65-180 million each. By contrast just under a half of the universities had an income less than $1 million.

207. Recent surveys of European KTOs conducted in 2008 and 2011 report a similar skewed distributions of licensing income: in both surveys **the leading 10% of universities accounted for approximately 85% of licence income.**[67] Furthermore these universities accounted for the majority share (at least 40%) of other knowledge transfer activities measured including patents granted, licences executed and spin-outs established (Figure 15).

208. Furthermore the majority of income is generated from patents and licences in the biomedical field – in the 2011 European survey, 89%, of €346 million in reported license income was from biomedical inventions.

Figure 15 ASTP survey 2008: percentage of KT outcomes by the leading 10% of PROs



Source ASTP[68]

[66] AUTM, op. cit (2010)

[67] Anthony Arundel, Catalina Bordoy, *Summary respondent report: ASTP survey for fiscal year 2008*, UNU-MERIT and ASTP, January 2010; Arundel et al. *op.cit* (2012)

[68] Arundel, op. cit (2010)

The skewed distribution is a result of the uncertainty inherent in innovation activities and that means it is not possible to predict which investments will be successful – and the variability in the quantity and quality of the research conducted at PROs. More research leads to more opportunities for the generating IP, while higher quality research institutions either generate 'better IP' or make more attractive partners for industry (or perhaps a combination of both). Therefore, in the USA in 2010 for example, the leading research PROs tend to dominate the licence income, including New York, Columbia and Stanford universities, the University of California system and MIT (Figure 16). The high ranking of the relatively small (in research activity terms) universities of Northwestern and Wake Forest in the list is the result of licensing income received from single highly successful patents in the medical field – again, reinforcing the skewed pattern of success. Once these technologies are no longer protected the income will dry up.

For this very reason the Technology Licensing Office at MIT reports that licensing income is not used as a key performance measure due to its high variability and the fact that success is beyond the control of the university. For similar reasons the AUTM survey, while reporting licensing income of PROs, has for a number of years not discussed or analysed the income data.[69]

As a result very few TTOs/KTOs, even in the USA, are financially self-sustainable. In 2009 only 16% of USA TTOs reported being self-sustaining in financial terms, with most relying on financial support from the central PRO budget.[70] This was also the case for the case studies with only three KTOs reporting themselves to self-financing (Oxford, Barcelona and Fraunhofer). The others were not covering their financial costs. Both Oxford and Barcelona are large research universities with long-standing KTOs with over 20 years experience. Oxford is a world-class research-intensive university, ranked in the top five internationally. As a result Oxford's KTO income is derived largely from IP, while Barcelona's is a mixture of IP and project management fees for contract R&D and competitive research projects. Fraunhofer Ventures supports the entire Fraunhofer Society and so has access to the outputs of the large pool of applied research conducted by its research institutes. However like Northwestern and Forest Bank universities in the USA, its licence income is dominated by a single patent (in this case for MP3 technology). Likewise, the CNRS KTO was self-financing until a few years ago when a single licence agreement came to an end.

[69] AUTM, *AUTM US Licensing Survey: FY 2007 – Survey Summary*
[70] Abrams et al. *op. cit* (2009)

Figure 16 USA university licensing income (2010) [71]

	University	Licensing income $M	% of total licensing income to US universities (cumulative)
1	Northwestern University	180	8%
2	New York University	178	15%
3	Columbia University	147	21%
4	University of California System	104	25%
5	Wake Forest University	86	29%
6	University of Minnesota	84	32%
7	Massachusetts Institute of Technology	69	35%
8	University of Washington/Washington Research Foundation	69	38%
9	Stanford University	65	41%
11	University of Wisconsin-Madison/Wisconsin Alumni Research Foundation	54	43%
12	California Institute of Technology	52	45%
13	University of Rochester	42	47%
14	University of Massachusetts	40	49%
15	University of Michigan	40	50%
16	University of Texas System	38	52%
17	University of Utah	38	54%
18	University of Florida	29	55%
19	University of Iowa Research Foundation	27	56%
20	Duke University	26	57%
	Total (top 20)	**1,368**	**57%**
	Total (all respondents)	**2,400**	

Aside from the self-financing KTOs studied, the PROs fund their KTOs through a combination of university central funds (block grants and/or overheads) and/or public funds specifically directed at KTOs and knowledge transfer activities. The funding model tends to reflect the wider national (or regional) system for funding PROs. Some countries fund KTOs directly, either during their set-up phase or both set-up ad on-going operations. The European Research Area Committee reported in 2011 that nine EU countries (and Norway)[72] have funding schemes in place for KTOs. Funding may be in the form of direct subsidies to PROs or competitive programmes. Other countries require that PROs conduct knowledge transfer but do not provide dedicated funding streams; in these cases KTOs are funded from PRO overheads.

[71] AUTM, op. cit. (2010)

[72] BE, CZ, DK, EE, ES, HU, IE, NL, UK (ERAC Working Group Report on Knowledge Transfer, 2011)

Income from other KT mechanisms (i.e. not from IP) such as collaborative/contract R&D and consultancy result in additional research income for researchers rather than the KTO itself. In some cases the KTO is able to charge a management fee on the research income it helps to generate but this is not the norm, not least because any public funding is unlikely to allow it. Nevertheless this income is important to the PRO. Figure 17 shows the income to UK universities generated by different KT mechanisms from public and private sources, with a little over 43% coming from private sources (34% from large businesses and 9% from SMEs). Collaborative and contract R&D provide the largest share of income, followed by activities in support of lifelong learning (CPD and CE) and consultancy, while IP exploitation accounts for only around 5% of the total income from KT.

In fact for many of the PROs studied, the remit to conduct *knowledge* rather than *technology* transfer results in an explicit requirement *not* to generate large-scale cash income. ETH Zurich, for example, has a mandate "to transfer technology through a liberal IP policy that maximizes impact and not financial returns." As a number of KTOs have reported, if income were the driver they would concentrate their activities on a more selective set of inventions that are the closest to commercialisation. Similarly it is fairly common for the PROs to take a small shareholding in spin-outs to ensure that the KTO remains aligned first and foremost to the PRO and not to one or two spin-outs. As reported by one PRO, a large shareholding would mean that the KTO (or even the PRO) would, in effect, be working for the spin-out and not for the PRO or the wider public good.

As presented in **Figure 6** in chapter 53 these other KT mechanisms generate a range of benefits to PROs and individual business as well as to society rather than direct financial income for the KTO. Therefore the KTO function (as well as knowledge transfer activities at the researcher level) serves an important function supporting and facilitating knowledge transfer and so needs to be funded. Various funding models are in place across Europe – with some countries (for example UK, Germany and Denmark) providing dedicated knowledge transfer funding programmes. However, in the current economic climate there is concern among some KTOs that dedicated public programmes and/or PRO support might be withdrawn in order to save costs. If so, it would be in complete contradiction to public policies at national and European levels calling for increased knowledge transfer in pursuit of increased innovation.

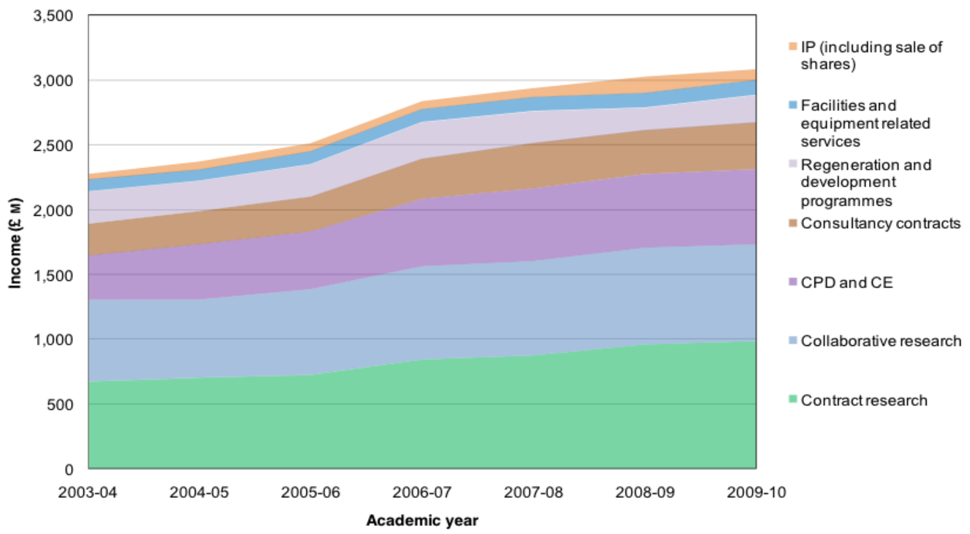
Comparisons of KTO funding models with the USA are difficult to make as the organisational structures are quire different. In the USA technology transfer office model still prevails, that is the offices focus mainly on IP exploitation. However, in the small sample of the USA TTOs studied only one of the three, MIT, is clearly self-financing from its IP income – while another, the University of North Carolina does not generate a sufficient IP income to cover all of its staff and external costs. Other studies show that that most USA TTOs are funded from the central university budget.[73] It is important to note that, while the Bayh-Dole Act placed a requirement on PROs to commercialise publicly funded research, it provided no funding to support them to do so. In fact the act has been described as "an unfunded mandate on U.S. academic institutions".[74] In general USA PROs face similar issues to those in Europe, - the TTO/ KTOs are very small compared to the level of research activity (Colorado reports that less than one-tenth of a percent is devoted to technology transfer) and the majority of TTO activity is in the medical and healthcare sector. This suggests that the European experience is not unusual.

[73] Abrams et al. *op. cit* (2009)

[74] Abrams et al. *op. cit* (2009)

Figure 17 PRO income from knowledge transfer mechanisms (UK)

Figure 2 Selected HE-BCI income streams 2003-2010 (real terms)



Source: HE-BCI Part B Tables 1, 2, 3 and 4c

Source: HEFCE, HEBCI report[75]

1. Assessing performance: knowledge transfer metrics

Getting the right metrics for knowledge transfer is essential, as ultimately the metrics guide behaviour – *what you measure is generally what you get*. Despite the wide range of knowledge transfer mechanisms in place across the PROs studied, most report against IP-related metrics such as numbers of invention disclosures, patents filed/ granted, numbers of licences signed, licence income and numbers of spin-outs created. Not only do these only predominantly measure direct outputs of IP activities rather than longer-term impacts (except for licence income), but they miss the vast majority of knowledge transfer activities. Most KTOs acknowledge that current metrics are insufficient but are not generally in a position to make improvements.

However, the good practice is available at both the national and institutional level. The UK has implemented an annual knowledge transfer survey of all KTOs based in Higher Education Institutes (HEIs). The survey has been developed over nearly 10 years and has created a stable set of metrics that attempt to measure knowledge transfer outputs that encompass a range of mechanisms including collaborative and contract R&D, consultancy and training for businesses (Figure 18). A recent study in the Netherlands has also resulted in the development of a set of metrics for knowledge transfer that address the different audiences (Figure 19).

[75] HEFCE, Higher Education – Business and Community Interaction Survey, 2009-10

Some KTOs use a similar metrics to the UK survey. ETH Zurich, for example measures the number of collaborations and number of contacts and Masaryk University in the Czech Republic measures the number of large projects financed. The University of Lund is attempting to assess the impact as well as the outputs of its activities; in 2011 it added the following metrics to track the growth of companies supported in terms of:

209. Turnover (in the companies supported / that were supported)

210. Employees (in the companies supported / that were supported)

211. Capital raising (in the companies supported / that were supported)

Lund also intends to collect a customer satisfaction survey from all of the companies with which it has interacted in any substantial way. They have also conducted a one-off study to trace the development of companies they have worked with based on published annual accounts. From this they found that over the last 10 years the companies that had been supported by KTO had created 2,000 jobs, raised SEK 2 billion in capital and achieved turnover of SEK 1.4 billion (figures accumulated 1999 to 2010).

Figure 18 Metrics used by the annual UK survey of knowledge transfer in HEIs[76]

Category	Metrics
INCOME	Collaborative research Contract research Consultancy Facilities and equipment-related services Continuing professional development and Continuing Education Regeneration and development programmes Intellectual property (including sale of shares)
OUTPUTS	Patent applications Patents granted Formal spin-offs established Formal spin-offs still active after three years
Whether the PRO provides:	UK higher education institutions that provide: Enquiry point for SMEs Short bespoke courses on client's premises Distance learning for businesses Required contracting system for all consultancy

[76] HEFCE, op. cit. (2010)

Figure 19 Newly developed metrics in the Netherlands (not yet implemented) [77]

Private sector	Professionals/ Public sector	General public
Patents	Articles in public journals	Popular science publications
Licenses	Products and services for public sector	Interviews en articles in the media
Spin-offs/start-ups	Guidelines and protocols public sector	Web publications
Products/services in private market	Education material / courses public sector	(Web- of digital) products for general public
Cooperation in research	Lectures for public organisations	Media coverage
Consultations by companies	Public positions, management function public organisations	Public lectures
Prices / awards by companies	Involvement end-users in research	Involvement of consumers in research
Public-private mobility	Consultation by public professionals	Prizes and awards
Courses Life long learning for companies	Courses Life long learning for public organisations	Public positions, management function public organisations
Alumni/PhDs working at companies	Awards/prizes by public organisations	References in the media
Turnover from patents and licenses	Alumni/PhDs working in the public sector	Sale products and services
Turnover from spin-offs en start-ups	References in public journals, policy documents, etc.	Use of products and services by general public (e.q. websites)
Turnover form products and services	Policy studies, studies for public organisations	Number of visitors at exhibitions, etc.
Citations by companies	Use of products and services in public sector	Number of exhibitions
Financial support companies for research	Financial support by public organisations	Catalogues
		Radio, TV programmes, dvds

[77] Rathenau Institute & Technopolis, aardevol Indicatoren voor Valorisatie, voor de Landelijke Commissie Valorisatie, June 2011

1. Good practice

The PROs studied report that there many sources of good practice available at both the regional, national and European level. As the profession of knowledge transfer has developed professional institutions and societies have been established such as ProTon Europe, the European Knowledge Transfer Association (created in 2003 by the European Commission and self supporting since 2007) and the Association of European Science and Technology Transfer Professionals (ASTP) created in 1999. Both offer best practice guidance and formal professional development for knowledge transfer staff. At the national and regional level many countries have networks and associations within which KTO (and wider PRO) staff can meet to exchange best practice such as the Institute for Knowledge Transfer in the UK, Netval in Italy, LIEU (Liaison Entreprises-Universités) in the French speaking community of Belgium. Some operate at the level of individual professionals and others at institutional level. In addition the League of European Research Universities (LERU) include knowledge transfer in its remit and has recently published an Advice Paper on TTOs.

When establishing or modifying a KTO, it is common for PROs to seek best practice and advice from other institutions. Some well-established PROs make their knowledge transfer and IP strategies and guidelines for staff publicly available on-line and these are valued highly by other KTOs. In some cases PROs setting up KTOs have visited a number of KTOs to better understand how they operate. However the low membership numbers in European level associations suggests that best practice is being shared largely between the early adopting countries with very little spreading to the later adopters and lagging countries and PROs. For example, there are currently 112 members of ProTon with the majority (92%) from EU15 countries (Figure 20). This is not a criticism of ProTon but a reflection of that fact that only a small number of Europe's PRO base of around 4,500 institutions are seeking best practice at a European level. Membership of national organisations is higher but this does not help the flow of best practice from, in particular the more experienced PROs and countries to the lagging ones. Therefore there is a significant opportunity to increase cross-border learning.

Nevertheless, there is a widespread view among KTOs that, while there is much to learn from each other, operational models cannot be directly copied. Each PRO operates within a different national, regional and institutional environment and with different underpinning traditions and cultures and therefore, each must identify the knowledge transfer mission and KTO model best suited to their context. The extent to which they focus on formal IP will tend to depend on the degree to which their external customers are science-based.

Figure 20 Membership of ProTon Europe by country

Country (EU15)	No. of members	Country (NMS)	No. of members
AUSTRIA	1	CROATIA	2
BELGIUM	9	CZECH REPUBLIC	3
DENMARK	6	SLOVAKIA	2
FINLAND	5		
FRANCE	4		
GERMANY	12		
GREECE	2		
HUNGARY	2		
IRELAND	11		
ITALY	28		
LUXEMBOURG	2		
NETHERLANDS	2		
PORTUGAL	6		
SPAIN	14		
UNITED KINGDOM	1		
EU15	103 (92%)	NMS	9 (8%)
Grand Total	112		

2. Pan-European knowledge transfer

As described in section 166.1.2 the geographical focus of PRO knowledge transfer strategies is dependent on the type of PRO, with the large internationally renowned research intensive PROs being the ones most likely to engage in international knowledge exchange. Therefore pan-European and wider international knowledge transfer has tended to be limited in scale and centred on the world-class institutions.

While the Commission has many programmes to support cross-border activities in research and innovation, the most comprehensive approach to date to integrating research, knowledge transfer capabilities *and* higher education are the Knowledge and Innovation Communities (KICs) of the European Institute for Innovation and Technology (EIT). The KICs have a strong focus on knowledge transfer and developing entrepreneurial skills in support of improved innovation performance. Building on the knowledge transfer capabilities of their constituent members, both in PROs and industry, they seek to increase opportunities to access research outputs, skills, and innovation partners across a wider geographical base.

Knowledge transfer is a key feature of the KICs; not only embedded in the requirements for formal partnerships between PROs and industry but also through the implementation of the full range of knowledge transfer mechanisms and KTO activities – developing strategic research agenda across all partners, supporting collaborative research, developing entrepreneurial skills, supporting IP exploitation and the creation and support of spin-outs (see Figure 21) etc.

However the KICs have only been fully operational for a relatively short period of time, 18 months at most, and therefore the extent of the effectiveness of their new models of engagement and their impact on innovation has yet to be seen. Nevertheless they have developed considerable experience in developing a number of different legal approaches to innovation partnerships and conducting cross-border knowledge transfer. Therefore they offer an important resource for learning and potential good practice in knowledge transfer more generally.

Figure 21 KICs planned activities for innovation support and entrepreneurialism[78]

Innovation Support and Entrepreneurialism

"**InnoEnergy's** planned activity in this field encompass: services for business creation; exploration and networking activities; innovation infrastructure (incubators, knowledge and innovation market platform, observatory and pre-seed fund), Innovation Network Development Unit and IP support activities.

Climate-KIC's 'Climate-KIC Entrepreneurs' innovation support component' "*seeks to offer support to the wider climate change entrepreneurs' community*", aiming to provide shared workspace and research facilities; as well as to exploit existing instruments and facilities at co-location centres (e.g. incubators and science parks, and courses). The intention is to expand existing innovation support infrastructures at co- location centres. Other activities planned include an Ideas Market Place (for entrepreneurs to share ideas), Greenhouse (providing six-month stipends for entrepreneurs to develop their innovative concepts up to proof-of-concept stage), SME innovation vouchers, a start-up advisory group and a climate venture competition.

In its 2011 Business Plan **ICT Labs** targets entrepreneurship support systems *("...a programme to stimulate birth and growth of new companies");* the EIT Innovation Radar (a virtual expert panel to assist in attaining "global thought leadership" in ICT); international best-practice benchmarking; networking platform for networking between entrepreneurs and venture capitalists; access to finance service; and pre-venture grants (fixed loans for researchers to pursue commercialisation possibilities).

In terms of commercialisation activity, KICs are largely still considering various types of support; but the indications are that technology transfer (large established firms and newer, smaller ones); product development and SME engagement will be targeted. There is evidence of enhanced institutional cooperation via KIC structures, and plans to use KICs to target the provision of support for start-up businesses, primarily by augmenting and/or exploiting existing provision in this field. Since many KIC partners already have access to technology/science parks and incubation **facilities, the value of KICs is more concerned with scale –** for example, KICs have reported leasing additional work-space in existing provision (to be used for industry partners to re-locate staff to work on joint projects)."

The evaluation also states that "Another likely outcome is that the rate of spin-offs emerging from existing incubation capacity will be increased through the application of KIC resources."

[78] DG EAC, External Evaluation of the European Institute of Innovation and Technology. Final Report On Evaluation May 2011

3. Summary

Knowledge transfer offices

212. The role of KTOs in innovation systems is to reduce the transaction costs of transferring uncertain and often un-codifiable knowledge from PROs to industry by

213. Bridging the cultural barriers between PRO researchers and industry

214. Professionalising the interactions and relationships

215. Helping PROs to become essential components of an inter-connected innovation system

6. In the early-adopting countries, PROs are no longer restricted by formal national laws or regulations that bar or hinder academics from participating in knowledge transfer and national innovation policies are in place that either require or encourage PROs to engage in knowledge transfer. In these countries, PROs have policies in place that define: IP ownership; responsibilities for managing and protecting IP; and for sharing of revenue derived from IP.

7. However just under a third of European Member States do not have national legislation/ regulation/ policies in place regarding the knowledge transfer role and IP ownership rules for PROs

8. The PROs with significant experience of knowledge transfer recognise that it encompasses a range of KT mechanisms and as a result they engage in, and support, the use of all mechanisms. Very few institutions have KTOs that focus solely on IP exploitation. The role of KTOs is, instead, to maximise the volume and impact of knowledge transfer activities carried out by academic staff through the professionalisation of the industrial interface and the widening of academic participation in knowledge transfer.

9. As a result, most PROs have institutional strategies that explicitly include a broad knowledge transfer mission. A member of the PRO leadership team, usually the vice-rector (or equivalent) for research, is allocated responsibility for knowledge transfer and there is an expectation that academic staff will increasingly engage in knowledge transfer activities. Furthermore, the term '*knowledge exchange*' is increasingly being used to better reflect the two-way flow of knowledge between PROs and businesses.

0. KTOs are structured in a number of ways both internal and external to the PRO and, as there are advantages and disadvantages of different approaches, no one model prevails. What is essential is that the structure is able to ensure a common mission for the KTO and academics while giving the KTO a fair degree of autonomy to undertake commercial negotiations with industrial organisations. The physical and intellectual proximity of the KTO to academic researchers is more important that the actual form of the organisational structure.

221. A knowledge transfer profession has been developing over the last 10-15 years, with KTOs increasingly staffed by knowledge transfer professionals. These are typically people with research backgrounds (often a PhD) and relevant business experience and/or specific professional experience in areas such as intellectual property, finance and marketing and communications.

222. Very few KTOs generate a surplus from their IP activities; and other KT mechanisms, such as consultancy and contract/collaborative R&D, do not generate revenue for the KTO itself. Therefore, even though KTOs are very small in resource terms making up less than 1% of PRO staff, most require financial support either from central PRO finances or dedicated public support from funding agencies.

223. Current knowledge transfer metrics focus too heavily on IP exploitation (numbers of invention disclosures, patents, licences and licence income etc.) rather than on the wider knowledge transfer activities undertaken. However a number of countries have developed more comprehensive metrics that could be used more widely across Europe.

224. Good practice is currently shared predominantly at national level. Membership of pan-European KT organisations, for example, is low and heavily focused on the EU15. Therefore opportunities for learning across the EU, especially from the experienced policy-makers, PROs and KTOs to the less experienced, are not being fully exploited.

225. Analysis

1. The three phases of development of a PRO knowledge exchange mission

The analysis of the PRO case studies suggests that the transition from two to three missions (teaching, research and knowledge transfer / exchange) occurs in three phases with each phase requiring different policy interventions and PRO activities (Figure 22):

226. **Phase 1: Establishing framework conditions** – the creation of formal policy support for knowledge exchange.[79] At a policy-making level this requires the removal of legal and regulatory barriers to knowledge exchange (where they still exist) and the establishment of a strong policy position with respect to knowledge exchange between PROs and industry (and other potential users of PRO-generated knowledge). This stage also requires that methods to financially support the third mission are considered and communicated clearly to PROs. The financing solution may vary with national context and may include direct funding through block or discretionary grants, competitive programmes or indirect funding via a full-economic costing funding model for public research activities. Policies need to acknowledge and promote the wider role of knowledge exchange (i.e. not just focused on IP exploitation) and enable and encourage PROs to deploy a wide range of exchange mechanisms

227. **Phase 2: Policy implementation** – the development and implementation of knowledge exchange strategies, policies, processes and governance structures at PROs – closely aligned with the research mission.

228. At the PRO level, this stage includes the development of a knowledge exchange strategy and the creation of professional support for knowledge exchange, typically via a KTO and the recruitment of professional knowledge exchange staff. However the strategy must acknowledge that academic staff are at the heart of the exchange process and operational support put in place, such as training and awareness raising, to encourage and enable their involvement. The knowledge exchange strategies of different types of PROs will be tailored to their regional/national context and societal roles i.e. large research intensive PROs with international reputations build strategies to serve a broad 'customer' base at regional, national and international levels, while regionally focused, less research-intensive PROs focus their strategies on a more local level.

229. During this phase policy-makers continue their support for knowledge exchange and may implement systems to monitor knowledge exchange activities.

230. **Phase 3: Embedding a knowledge exchange (third) mission** – consolidating a knowledge exchange mission and culture within PROs and across the economy more

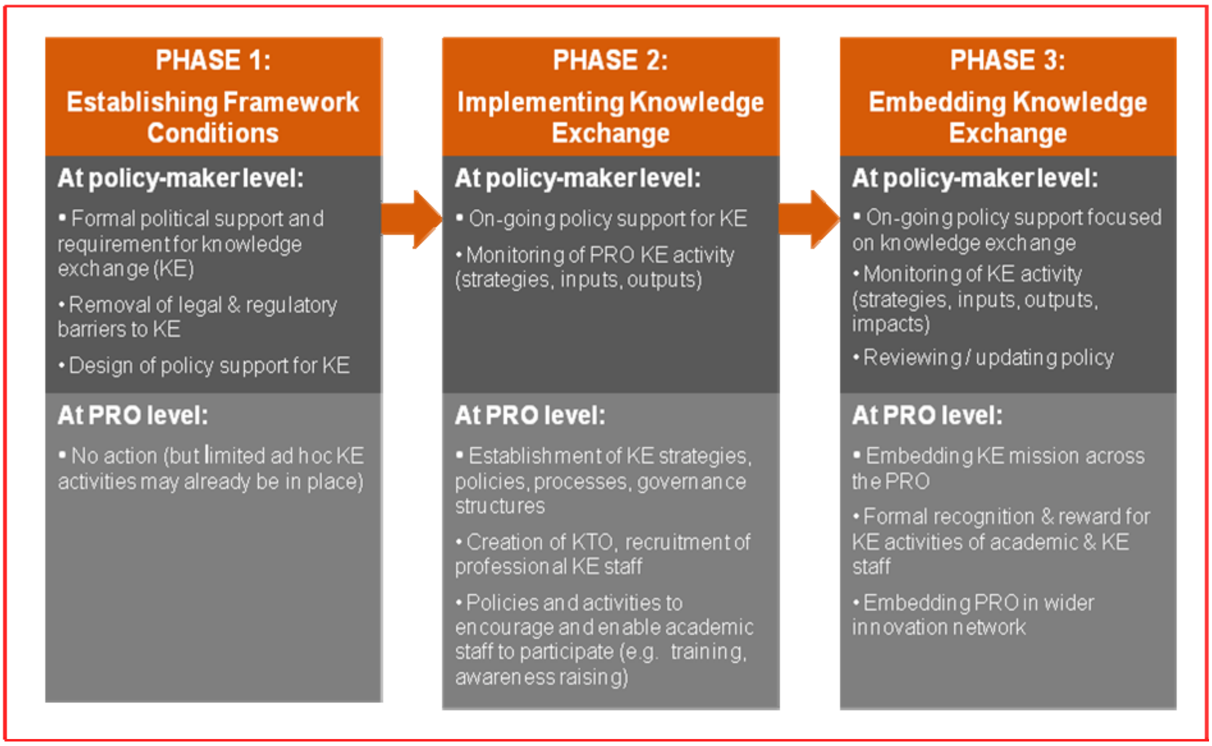
[79] Historically this support may have focused on technology or knowledge transfer but we now use the wider term 'knowledge exchange' to reflect the more recent movements that have taken place in policy thinking in both policy thinking and from the perspective of those implementing PRO-industry interactions.

widely. This stage has not yet been fully achieved by any PROs, but would be expected to entail:

231. The development of an outward-looking and entrepreneurial culture within each PRO, with appropriate incentives and rewards for academics and KTO staff. Over time, embedding PROs within appropriate professional, sector and disciplinary networks. Leading, ultimately, to an increase in the volume of knowledge exchange activity and an increase in the impact of PROs on society.

232. During this phase policy-makers continue their support for knowledge exchange, monitor outputs and impacts and may consider reviewing and updating knowledge exchange policy.

Figure 22 Transition from two to three missions



Source: Technopolis

1. Where are European PROs in the journey?

1. The sample of PROs

The PROs studied are in Phase 2: appropriate laws and policies have been enacted across most EU member states giving PROs a third mission to conduct knowledge exchange in support of societal benefit; and PROs have established institutional knowledge exchange strategies and KTOs or similar functions to support professional and effective knowledge exchange.

None of the PROs studied has truly reached Phase 3, except perhaps MIT. Achieving a fully embedded knowledge exchange mission will take considerable time. Behavioural and cultural change is a notoriously slow process and there is still resistance to change within the academic community. Even amongst the early-adopters there is still a long way to go before the third mission is a truly embedded feature of PROs.

The earliest adopters who have been engaged in some form of pro-active technology/knowledge transfer and exchange for over 20 years, such as the Universities of Oxford and Barcelona, and have yet to achieve Phase 3. However, their experience enables them to identify the remaining challenges and some have started to take steps to address them.

The three phases as described above characterise the third mission throughout as *knowledge exchange*, where in reality, for many early-adopters phases 1 and 2 have also included a transition both at national and individual PRO level, from a technology transfer to a broader knowledge transfer and exchange focus.

2. *The sample vs. the population*

In many ways our sample was skewed towards individual PROs that have a well-defined KTO function – as they were both readily identifiable and willing to engage in the study. As a result, many of them are at a reasonable stage of development towards Phase 3 and an embedded knowledge exchange mission.

However looking at national innovation systems in Europe (and their PROs) more generally, each is at a different stage of development towards an embedded knowledge exchange mission. This is mainly due to the fact that European countries started on the journey at very different times. Evidence suggests that a large proportion of European PROs still have a long way to go; as illustrated in **Figure 10** the ERAC review of knowledge transfer in Europe reports that 70% of current Member States have put in place laws, regulations and/or policies for knowledge exchange, with many of these countries also providing funding to support capacity building for knowledge exchange and the development of operational processes.[80] Therefore most EU countries have reached Phase 1 with a sub-set, such as the early adopting countries in this study, in Phase 2. Nevertheless, this suggests that nearly a third of Member States (not all of which are New Member States) have yet to reach Phase 1 and so there is still considerable work to be done to develop the third mission in these countries to ensure their PROs can fully contribute to innovation.

The range of experience in knowledge exchange at both national and PRO level means that those in the early phases of development have the potential to learn from the more experienced. A particular example of learning would be to avoid focusing policy at national or institutional level on increasing or maximising PRO income from exploiting IP as this is only possible for a small number of PROs (as shown in section 205.3) and may deflect resources from other more productive knowledge exchange activities.

[80] ERAC, op. cit (2011)

2. Barriers to achieving an embedded knowledge exchange mission

The PROs that have reached Phase 2 are able to identify the barriers that remain to developing a fully embedded third mission. For this group, policies, processes and structures for knowledge exchange are in place at an operational level. Procedures for conducting contract and collaborative R&D and consultancy are being streamlined, although there are still improvements to be made. The most significant remaining barriers are, from the KTO perspective, found in the 'softer' areas of culture and tradition. In particular the two key areas:

Lack of the culture of knowledge exchange among the academic community

This is changing but there is still a long way to go. While some academics engage willingly and enthusiastically in knowledge exchange, many still do not believe that it is part of their role as academic researchers. KTOs continue to work hard to raise awareness of the benefits of knowledge transfer and exchange to the academic community. Many PROs now provide (or require) training in entrepreneurship to postgraduate students (and sometime undergraduates) to prepare them for a career within academia or in the private sector, and as a result younger researchers are often more at ease with the third mission. However many researchers remain to be convinced, not least because the academic career system does not recognise or reward participation in knowledge exchange and entrepreneurial activities. Academics are not, in the main, motivated by financial gain but by the recognition of their peers and career progress within the academic profession. However as long as academic career progression remains rewarded in terms of research and teaching activities, knowledge exchange will remain, to a large extent, extra-curricular.

However it is important to get the right metrics and incentives for academics and maintain an appropriate balance between openness (i.e. publication) and protection (i.e. IP guidelines, agreements in collaborative R&D for example). This is particularly important in the early-stage of academic careers as publications during PhDs and post-doctoral posts are essential to developing research reputations and career progression.

A number of PROs have begun to address this issue and have changed or are considering changing the academic career development system. In some countries this is possible at the institutional level where PROs, universities in particular, have a high degree of autonomy (e.g. in the UK) but in other countries academic careers are defined at the national level (e.g. the civil service structure for academic careers in Spain). A small number of examples of early adopters of career measures can be found:

233. The University of Hertfordshire has developed an academic career path that recognises and rewards knowledge transfer. It enables academics who engage in significant levels of knowledge transfer to progress in their career (and even select this career path) to full professor. A small number of academics are currently on this career path and the first professorship was recently awarded under the scheme. In addition, the university has a resource planning (IT) system that fully recognises knowledge transfer activities meaning that time can be allocated to knowledge transfer and therefore it is not treated as 'extra curricular'

234. At Delft University of Technology academics are subject to regular reviews on their knowledge transfer (or 'valorisation') activities that contribute to their career progression. Also, internal allocations for knowledge transfer results in more funding, for the academic, from central funding resources.

235. University College Dublin also includes innovation as a criterion for promotion for academics

236. Other European universities have also made moves in this direction – including the universities of Aalto and Eindhoven, and in Italy changes at the national level have led to a new system that includes external income as a measure of performance of individual academics.

Recruiting and retaining professional knowledge exchange staff

While the technology transfer and knowledge exchange profession has grown considerably over the last 10 to 15 years, PROs still experience difficulties recruiting and retaining KTO staff. While in some countries the pool of professionals maybe still be relatively small the larger issue is the ability to reward staff appropriately. It is common practice for KTO staff to be regarded as part of the PRO's administrative structure. This can place restrictions on a PRO's ability to attract and reward high quality staff with both academic and business experience. Restrictions may be based in national structures that define PRO career and pay systems or alternatively in a culture of lower salaries for administrative posts. Either way staff are either difficult to find or, once in post, highly mobile. As for the academics, career structures for KTO staff need to be suitably flexible to recognise and reward them as appropriate.

Lack of suitable metrics for knowledge exchange

Metrics to assess KTO performance and impact remain focused on technology transfer outputs – numbers of invention disclosures, patents filed and approved, licence agreements and licence income, etc. This is due, in part, to the initial focus on technology transfer but also the convenience of measuring outputs that are easily identifiable and countable. Nonetheless better metrics are required as metrics incentivise and drive behaviour. Outputs of other knowledge exchange mechanisms *are* countable (such as the value of consultancy or contract R&D) and a number of countries have developed metrics and data collection processes to assess knowledge exchange activity at a national, as well as PRO, scale.

Insufficient sharing of good practice at European level and barriers to cross-border knowledge exchange

Considerable experience has been gained in the early-adopting countries and PROs but this is not being shared as widely as it could be to enable later adopters to benefit. As these countries /PROs move from phase 1 to phase 2 (and later to phase 3) opportunities for them to learn from earlier experience would enable them to avoid pitfalls and climb the learning curve much more quickly. Furthermore the development of more consistent practices across Europe would better facilitate cross-border knowledge exchange as differences in strategies and policies at national and PRO level can impede contract negotiations for cross-border knowledge exchange, particularly where several PROs are working together with businesses in joint R&D activities. Differences in IP arrangements for example are often a cause of contention in R&D contract negotiations, slowing down the process and delaying the start of research activities.

An over-focus on technology (IP-based) transfer

While many countries now focus policy on knowledge exchange rather than technology transfer this is not the case everywhere and this is an area where later adopters can benefit earlier experiences. IP exploitation needs to be acknowledged as just one element in knowledge exchange – more suitable for some PROs and some sectors than others. For most PROs it will not be the main mechanism deployed. National, European and institutional policies that regard income from IP as a key output of knowledge exchange lead to KTO incentive structures that present additional barriers, due to over-protection of IP, to the flow and exchange of knowledge between PROs and industry. Furthermore an over-aggressive approach to IP by PROs can act as a barrier to effective engagement with industry. Fundamentally PROs need to maintain their public good role in society and their third mission needs to be focused on diffusing knowledge to where it can be put to best use and ensuring the flow of knowledge into institutions to inform research. Therefore third mission /knowledge exchange policies at European, national and PRO levels need to strike the right balance between openness and protection of their research outputs.

237. Summary and Conclusions

1. Knowledge exchange is required to support innovation

As our understanding of innovation has developed over the past few decades, it has shifted from a linear model where innovation is a result of inventions and knowledge 'pushed' out of the research-base or 'pulled' by market demand towards an innovation systems model where innovation is a complex process shaped, influenced and enabled by a range of actors, infrastructures, framework conditions and market demands. Businesses are the main innovation actors in the innovation system, seeking opportunities to utilise their technological, human and organisational capabilities to innovate in order to meet, or even create, market needs. The extent to which they are stimulated, supported and enabled to innovate or, alternatively, hindered and discouraged, depends in how well the system functions. As a system it not only requires the right components - actors, infrastructure, frameworks and incentives etc. - but also well-functioning networks connecting its components and facilitating the flow of capital, skills and knowledge.

PROs, as actors within innovation systems, have traditionally played a role via their core missions of education and research – providing skilled graduates to industry and contributing to the available knowledge stock. However, over the past 15-20 years they have been increasingly assigned an additional *third mission* to pro-actively transfer their research-generated knowledge to industry and to society more widely. Early policy, based upon the linear model of innovation and modelled on changes in the system in the USA, conceived this as a direct role in the commercialisation of their own research results via the exploitation of protectable intellectual property through patenting, licensing and the creation of spin-off businesses – activities generally referred to as *technology transfer*. This led to legal and regulatory changes that enabled PROs to engage in technology transfer, removing legal barriers to business engagement and, most notably, the transfer of IP ownership of the outputs of publicly funded research from either individual researchers or the state to the PROs themselves - a process that essentially duplicated the Bayh-Dole Act in the USA, with the aim of replicating its perceived success. Policy changes also required or encouraged (usually through funding) PROs to establish processes and resources to undertake technology transfer leading to the creation of Technology Transfer Offices (TTOs) tasked with managing and exploiting PRO IP. Early mover countries, largely in the EU15, went through this process resulting in the establishment of TTOs from as early as the 1980s, in Spain and the UK for example, throughout the 1990s and into the early 2000s. Similar activity commenced in New Member States, in most cases, somewhat later starting from the mid 2000s and stimulated by similar policy changes.

However during this time the conceptualisation of PROs' third mission has developed into a broader mission of *knowledge transfer and knowledge exchange* reflecting not only the position of PROs within the more complex systems model of innovation but also reality of industry interactions and knowledge flows as conducted and experienced by PROs themselves. Both the innovation systems model and empirical studies show that innovation is a complex process involving many sources of knowledge and skills both internal and external to individual businesses. PROs are just one source of external knowledge for innovation activities and businesses interact with them in a variety of ways – many of which pre-date the formal requirement of a third mission. Importantly, businesses regard more 'traditional' KT mechanisms as more important than IP exploitation.

Academic publications are viewed as the most important mechanism for transferring knowledge from PROs to industry, followed by more in-depth forms of interaction such as consultancy, contract and collaborative R&D and accessing research skills (through hiring postgraduates, staff exchanges etc.), and exploiting IP being the least important mechanism. This pattern reflects the complexity of the research-generated knowledge and the need to transfer both codified and tacit knowledge to enable its re-use in a business context. Publications and published patent texts transfer codified knowledge and also provide information as to who holds relevant knowledge, while more interactive KT mechanisms such as contract and collaborative R&D, accessing research skills and informal interactions enable the flow of tacit knowledge.

Where IP is concerned, a standalone IP licence can only transfer codified knowledge; however most IP transactions between PROs and business also involve further more in-depth interactions, such as contract and collaborative R&D, to transfer tacit knowledge critical to the development and commercialisation of what are, in most cases, very early stage technologies. Therefore the exploitation of PRO IP is rarely a simple market transaction that transfers technology at a market price, but a much more complex process of knowledge transfer occurring over a period of time. Furthermore IP exploitation as a KT mechanism is suited to some sectors more than others. It is relatively more important to science-based industries such as pharmaceuticals, electrical/ electronics, chemical engineering and advanced materials that conduct significant levels of in-house R&D and also tend to rely on IP to protect their innovations. These sectors also make wide use of other knowledge transfer mechanisms to continually update their knowledge base.

A key feature of innovation is that not all sectors innovate in the same way. Sectors focus their innovation activities on different aspects of their business (process efficiency, incremental change, technological leadership, proprietary systems), make use of different external innovation inputs (customers, suppliers, standards, PROs etc.), and use different mechanisms to appropriate and protect their innovations (secrecy, formal IP, professional skills, technical leadership etc.). As a result not all sectors interact with PROs to the same extent or in the same way – and therefore, when they interact with PROs, they require different types of knowledge and different methods of transfer.

Very few PROs, in Europe and the USA, produce sufficient volumes of IP to generate enough income to cover the costs of the KTO. The 'lottery' of early-stage technologies where most will fail to make it to market, results in a highly skewed distribution of revenue from IP, with a small number of PROs receiving most of the income. It is important to recognise that this pattern is a feature of technology development and commercialisation rather than a failing in knowledge transfer policies and PRO activities. However, due to the need for deeper academic-industry partnerships to transfer of tacit knowledge as well as codified IP, the majority of IP agreements are with businesses already known to particular researchers, and therefore policy support for wider knowledge transfer, valuable in its own right, will also enhance the IP transfer mechanism.

Many of the early adopters of the third mission policies both at policy-maker and PRO level have recognised that IP based technology transfer is not sufficient to transfer research-generated knowledge to where it can be best used in pursuit of innovation and economic growth. IP exploitation is just one mechanism in a *broader knowledge exchange mission* that uses a variety of mechanisms to engage with businesses in order to support and contribute to their innovation activities.

This is evidenced in the wide remits of many of the KTOs studied. In the systems model of innovation, the role of KTOs is to overcome systemic failures; to bridge the organisational and cultural gaps between business and PROs and so reduce the transaction costs of transferring uncertain and un-codifiable knowledge and maximise the amount of knowledge transferred and, in the longer term, develop deep and sustainable innovation networks encompassing both businesses and PROs as part of an inter-connected and well-functioning innovation system. PROs also recognise that knowledge flow is a two-way process with PROs also gaining from their interactions with businesses and the term *knowledge transfer* is beginning to be replaced by the term *knowledge exchange*.

The presence of KTOs does not in itself guarantee more effective and efficient knowledge exchange and, as additional actors in the innovation system, KTOs must be structured and operated so that do not, themselves, become a barrier to knowledge exchange. Over-protection of IP, unrealistic valuations of IP and an incentive process focused on income to the PRO may well impede knowledge exchange. The third mission should not detract from the public good role of PROs in society and therefore regional, national and European knowledge exchange policies and their implementation by PROs should retain the public good focus and aim to ensure the flow of research-generated knowledge to where it can be put to best use in society.

2. Creating an embedded knowledge exchange mission takes time

The development of a third mission for PROs takes time. The extent of the change required varies from country to country and PRO to PRO. For some institutions, knowledge exchange, or at least some KT mechanisms, have been in place for many years though generally in an ad hoc manner, while for others engagement with businesses was effectively banned or highly discouraged. Therefore the development from no (or limited) knowledge exchange to a well-functioning innovation system containing pro-active PROs with well-founded and embedded knowledge exchange strategies and processes (including KTOs) requires significant cultural as well as strategic and operational changes within PROs. This process can be categorised as three phases:

238. **Phase 1: Establishing framework conditions** – the creation of formal policy support for knowledge exchange. At a policy-making level this requires the removal of legal and regulatory barriers to knowledge exchange (where they exist) and the establishment of a strong policy position with respect to knowledge exchange between PROs and industry (and other potential users of PRO-generated knowledge).

239. **Phase 2: Implementation** – the development and implementation of knowledge exchange (or 'third mission') strategies, policies, processes and governance structures at PROs – closely aligned with the research mission. This includes the creation of a KTO and the recruitment of professional knowledge exchange staff, while also acknowledging that academic staff are at the heart of knowledge exchange and putting processes in place, such as training and awareness raising, to encourage and enable their pro-active participation.

240. **Phase 3: Embedding a knowledge exchange mission** – consolidating the knowledge exchange mission and embedding a knowledge exchange culture across the PRO and developing an outward-looking and entrepreneurial culture throughout the PRO, with appropriate incentives and rewards for academics and KTO staff and, over time, embedding the PRO within appropriate professional, sector and disciplinary networks.

The majority of European countries have reached phase 1 but their individual PROs are in various stages of development in phase 2. No European PROs can be considered to have fully reached phase 3 but a number of PROs in the early-adopting countries are getting close to that point. Achieving a fully embedded knowledge transfer mission will take considerable time – behavioural and cultural change is a notoriously slow process and there is still resistance to change among the academic community. Even amongst the early-adopters of knowledge transfer there is still a long way to go before the third mission is a truly embedded feature of PROs and even the very first earliest adopting PROs, with more than 20 years experience in technology transfer and knowledge exchange, are coming close, have yet to achieve phase 3. However their experience has enabled them to identify the remaining challenges and some have started to take steps to address them.

Of more concern is the large number of PROs that still have a long way to go. Nearly a third of Member States have yet to reach phase 1. These countries need strong encouragement to implement third mission policies and guidance and access to good practice to move quickly and develop effective knowledge exchange strategies and practices. There is no one-size-fits-all model for individual KTOs in terms of organisation structure, size and processes. Each PRO designs a KTO and supporting processes to suit its institutional, national, industrial and historical context. KTOs can, and do, learn from each other but models are rarely copied directly but are adapted to meet individual PRO needs.

1. Barriers to knowledge exchange remain

Even for those countries that have made significant progress in knowledge exchange, to achieve a fully embedded third mission in PROs a number of remaining challenges need to be overcome:

241. **An <u>over-focus</u> on technology (IP-based) transfer can hinder knowledge exchange between PROs** and businesses. The *knowledge exchange,* as opposed to solely technology transfer role of PROs is not fully recognised in all relevant policy. IP exploitation needs to be acknowledged as just one element in knowledge exchange – more suitable for some PROs and some sectors than others. For most PROs it will not be the main mechanism deployed. Policies that regard income from IP as a key output of knowledge exchange lead to KTO incentive structures that can present additional barriers, through an over-protection of IP, to the flow and exchange of knowledge between PROs and industry.

242. **A lack of well-defined metrics for knowledge exchange.** Linked to the point above is the fact that metrics to assess KTO performance and impact remain focused on technology transfer outputs – numbers of invention disclosures, patents filed and approved, licence agreements and licence income, etc. This is due, in part, to the initial focus on technology transfer but also the convenience of measuring outputs that are easily identifiable and countable. Nonetheless better metrics are required as metrics incentivise and drive behaviour. Outputs of other knowledge exchange mechanisms are countable (such as the value of consultancy or contract R&D) and a number of countries have developed metrics and data collection processes to assess knowledge transfer activity at a national, as well as PRO, scale.

243. **Lack of the culture of knowledge exchange among the academic community.** A key issue is the career development path for academics. In the majority of PROs recognition and reward systems for academics remain based on the two traditional missions of education and research, resulting in no incentive, in career terms, to engage in knowledge exchange This means that, at present, only those academics personally incentivised to work with businesses do so. This is starting to change, PROs are recognising this as a barrier and some have made changes to career structures at an institutional level. However in some countries academic career structures are defined at the national level and therefore action is required at that level.

244. **Recruiting and retaining professional knowledge exchange staff.** Despite the development and growth of a technology transfer and knowledge exchange profession, PROs still experience difficulties recruiting and retaining KTO staff. While in many countries the pool of professionals is still relatively small, the more significant issue is the ability to reward staff appropriately. It is common practice in several European countries for KTO staff to be regarded as part of the PRO's administrative structure. This can place restrictions on a PRO's ability to pay appropriate salaries to attract and retain high quality staff with both academic and business experience. As for the academics, career structures for KTO staff need to be suitably flexible to recognise and reward as appropriate.

245. **Cross-border knowledge exchange.** Differences in knowledge exchange strategies and policies at national and PRO level can impede contract negotiations for cross-border knowledge exchange, particularly where several PROs are working together with businesses in joint R&D activities. IP arrangements are often a cause of contention in R&D contract negotiations, slowing down the process and delaying the start of research activities. The issues are not only IP sharing arrangements (although these do vary country to country and PRO to PRO) but also definitions of, and agreements as to what is considered background and foreground IP.

246. **Good practice is not shared as widely as it could be.** Considerable experience has been gained in the early-adopting countries and PROs but this is not being shared as widely as it could be to enable later adopters to benefit. As these countries /PROs move from phase 1 to phase 2 (and later to phase 3) opportunities for them to learn from earlier experience would enable them to avoid pitfalls and climb the learning curve much more quickly. The lagging countries will face these issues as they develop their knowledge exchange policies and practices and therefore accessing best practice will enable them to reach an embedded third mission as quickly and effectively as possible.

247. Policy Options

Innovation policy needs to ensure that the complete innovation system is fully functional – that the relevant components exist and are effective, and that the interconnections and networks between the various components are in place and work successfully. The role of policy is then to address those aspects of the system that are missing or not working effectively. Innovation policy is then directed at various features of the system with a strong focus on supporting businesses to innovate and investing in R&D. There are numerous policy options available including those directed at supporting specific actors or actions within the system and those directed at framework improving conditions and incentives for innovation[81] with individual countries selecting a policy mix to suit their context.

Knowledge transfer between PROs and business is just one feature of the innovation system, albeit it an important one that represents a key set of connections between PRO-generated knowledge and those best placed to make use of it. In fact the process of interactions between PROs and business is more accurately described as *knowledge exchange* and therefore we use this term in the policy options that follow. These options focus on policies that can improve the quantity and quality of knowledge exchange and addresses areas where policies for knowledge exchange interact with /overlap with other broader innovation policy interventions.

Knowledge exchange NOT technology transfer is required to support innovation

The role of PROs in the innovation network is to create knowledge and make it available to those best placed to make use of it for economic and social benefit. To achieve this PROs make use of a wide range of knowledge exchange mechanisms, selecting those most appropriate to the discipline, sector and individual business concerned. The majority of knowledge exchange occurs through mechanisms other than 'technology transfer' i.e. the exploitation of formal IP and, furthermore that an over-focus on IP protection can act as a barrier to knowledge exchange. The majority of substantive knowledge exchange takes place between individual researchers and people in businesses and, therefore, the role of the KTO is to facilitate and support the exchange of knowledge between PRO researchers and other economic actors.

Therefore to support and encourage knowledge exchange public policy needs to:

248. Recognise the public good role of PROs and **focus policy on knowledge exchange not technology transfer** to ensure that policy interventions focus on knowledge diffusion and the building of long-term research relationships with business, rather solely on the protection and exploitation of PRO-generated IP. An over-focus on IP can lead to KTOs that impede rather than improve the role of PROs in the innovation system.

249. **Require that PROs embrace knowledge exchange as a third mission based on the principle of knowledge diffusion and a clear understanding that revenue generation is not its prime objective.** This is includes (but is not limited to):

250. Ensure any remaining barriers to implementing a third mission are removed at the national level and that the third mission is incorporated into relevant legislation / regulation / policies in all Member States

[81] Appendix D provides a taxonomy of policy types

251. Ensure that the extended KTO model (i.e. not a TTO) is rolled out in smaller and often more regional universities as well as in the leading institutions

252. Ensure that policy-makers and individual PROs can access knowledge exchange best practice

253. **Ensure that businesses are supported to interact with PROs**. To ensure PROs maintain, deepen and expand their position in innovation networks, innovation national and European policies need to enable businesses to find and interact with relevant PROs and academics. This includes support for large companies that are able to engage in collaborative R&D as well tools such as innovation vouchers to assist SMEs.

Policy Options

A. Commission Communication on Knowledge Exchange

The Innovation Union and Horizon 2020 place considerable emphasis on knowledge exchange, but as the analysis has shown there is still a long way to go to achieve a fully embedded knowledge exchange culture in European PROs. The European Commission Communication and the Council Resolution of 2007/08[82] identified many of the key issues in knowledge exchange listed above, and embrace the concept of knowledge exchange not technology transfer. However while some EU countries have embraced the concept at a national level and some PROs are moving ahead with implementing policies, several Member States and many individual PROs across Europe lag behind.

The Commission and Council policy recommendations were published 4-5 years ago and it is timely, in light of the policy developments of Innovation Union and Horizon 2020, to increase awareness of the importance of knowledge exchange and to update and improve policy recommendations. Therefore a Communication on knowledge exchange is needed to focus attention on recommendations for policy interventions at European and national levels.

What to do	How to do it	Who should do it
Research and publish a new Commission Communication on Knowledge Exchange	Review progress towards embedding knowledge exchange between PROs and industry in ERA policy, previous knowledge transfer Communications and the forthcoming Horizon 2020. Identify gaps in order to update and improve the Communication.	DG-Research and DG-Education and Culture in cooperation

[82] COM (2007) 182 final; Commission Recommendation on the management of intellectual property in knowledge transfer activities and Code of Practice for universities and other public research organisations (COM(2008)1329); Council Resolution on the management of intellectual property in knowledge transfer activities and on a Code of Practice for universities and other public research organisations – "IP Charter Initiative" (10323/08)

B. Greater Use of Structural Funds to Support the Development of Capacities for Knowledge Exchange

While structural funds have a focus on innovation, DG Regio could be encouraged to place a greater emphasis on the development of knowledge exchange capabilities and capacities within regional PROs and to ensure that regional innovation strategies avoid the technology transfer paradigm. However, this support should ensure that lagging countries are able to maximise opportunities to learn from experienced countries – at both the level of policy-makers and individual PROs.

What to do	How to do it	Who should do it
Encourage Member States to incorporate knowledge exchange components in Regional Innovation System strategies (as part of their wider Smart Specialisation Strategies)	Incorporate knowledge exchange criteria into Regional Innovation System guidelines	DG-Regions Member State regions in receipt of structural funds

C. Support for Sharing Good Practice

Early adopters have gained considerable experience in knowledge exchange and while there is no one-size-fits-all approach to knowledge exchange strategies and operations, there is a wealth of best practice in existence across Europe. This needs to be identified and made more widely available, particularly to the lagging countries to enable them to climb the learning curve faster.

Policy options include:

254. Public financial support for the identification, collection and pro-active dissemination of good practice widely across the EU with a particular focus on improving lagging countries. New material is not necessarily needed, many PROs publish knowledge exchange strategies, policies and guideline; the issue is identification of good practice tools and information, awareness and dissemination.

255. Good practice support may also include widening the provision of professional networks in knowledge exchange to meet the needs of different types of PROs, from the research intensive to the more regional less research-intensive institutions. This might be achieved through providing public financial support for extending the reach of existing networking organisations or supporting the creation of new organisations to meet the specific needs of different types of PROs. To date many networking organisations are predominantly focused on technology rather knowledge exchange.

256. Public financial support to PROs in the process of establishing (or developing) a mission for knowledge exchange and KTOs to access best practice 'hands-on' through visiting established KTOs, developing relationships with more experienced players and acquiring professional mentors. EU structural funds could be directed to such activities in support of capability and capacity building in knowledge exchange.

What to do	How to do it	Who should do it
Establish a European Knowledge Exchange Observatory	Build or extend an EU-wide data collection and analysis network, with an associated benchmarking and training function. Ensure that the network has the broadest coverage of knowledge exchange mechanisms and processes.	DG-Research and DG-Education and Culture in cooperation should fund a network to do this
Task the Observatory with developing benchmarks, experience exchanges and trainings, aimed at improving knowledge exchange practice, especially in lagging institutions and regions	Establish good practice models, training, mentoring and support especially for PROs in less favoured regions and for smaller universities. Ensure tackling the needs of SMEs is part of the agenda.	As above

D. Pan-European Knowledge Exchange

Much knowledge exchange activity takes place at the national level and while in many circumstances this is entirely appropriate, in high-technology sectors international knowledge transfer is essential. Considerable experience exists across Europe acquired from one-to-one partnerships and collaborative R&D supported by the Framework Programmes, nevertheless challenges remain particularly with respect to contract negotiations and issues relating to IP. Furthermore, the European Institute of Innovation and Technology (EIT) and its Knowledge and Innovation Communities (KICs) have recently been through the process of establishing complex pan-European innovation partnerships and they offer opportunities for further learning.

Policy options include:

257. A study to identify and disseminate best practice in pan-European knowledge exchange with a particular focus on the Framework Programmes – to identify, for example, best practice in contracts and collaboration agreements to act as exemplars for future partnerships (as has been done in the UK and Germany for example).[83]

[83] *University – Business Cooperation: Thematic Forum on Knowledge Transfer*, European Commission November 7, 2008

258. The KICs are intended as a new model in innovation partnerships and knowledge exchange and their experience in the years ahead offers opportunities for improving European practice, they have first-hand practical experience of the barriers to pan-European knowledge exchange; and secondly, the solutions they devise will potentially provide an additional source of good practice. The KICs have been fully operational for a relatively short period of time, 18 months at most, and therefore useful information about their practical experience in delivering pan-European knowledge exchange is only just be becoming available. Therefore it is timely for the Commission to implement a process to regularly monitor and review the knowledge exchange strategies and processes of the KICs in order to: review the extent to which they are implementing a knowledge exchange rather than (solely) technology transfer model; ensure that knowledge exchange is appropriately monitored and measured; identify significant barriers to pan-European knowledge exchange; identify good practice as well as any unforeseen implications for the participating organisations.

What to do	How to do it	Who should do it
Study, identify and disseminate knowledge exchange good practice related to the Framework Programme, EIT and other EU-level R&D initiatives	Launch an external study. Embed the results in the dissemination and training work of the Observatory	DG-Research to fund the study

Accelerating the Modernisation Agenda for PROs and Embedding the Third Mission

European Higher Education institutes (HEIs) are under-going a process of modernisation on order to strengthen the competitiveness of European higher education and to contribute more effectively to knowledge based economy, with Member States at different stages of modernisation. Academic staff are at the heart of HEIs and at the heart of knowledge exchange and therefore cultural change at within the academic community is essential to the modernisation agenda – institutional cultures cannot change fully without cultural change among academics.

A key issue for knowledge exchange is the introduction of a third mission as a strategic objective of PROs without any corresponding change in the underpinning practical structures and operational processes. The funding and reward and recognition systems for both individual PROs and individual academics remain fundamentally focused on two missions – teaching and research. **The third mission will not become embedded until institutions and academics are funded and rewarded based on all three strategic missions – teaching, research and knowledge exchange.** Until this is the case the third mission will remain a marginal focus of PRO activity.

An important aspect of this is the fact that academic careers remain based on two missions, i.e. education and research. Knowledge exchange, and the broader concept of the knowledge triangle, will never become a truly embedded feature of PROs while their academic staff are able to view knowledge exchange as an additional or discretionary activity. However European policy on the modernisation agenda for HEIs barely recognises this important barrier to modernisation. However, PROs in early adopter countries are starting to recognise this as an issue and a small number have started to modify their career structures to recognise and reward knowledge exchange activities in addition to education and research. These offer an opportunity for the wider community to learn from their experience.

A similar issue exists with respect to the reward and recognition of professional KTO staff. Knowledge transfer and knowledge exchange requires a number of specialist skills – marketing and communications, understanding market /individual business needs, 'selling' (contract and collaborative R&D, consultancy, licences etc.), negotiation, contracts, relationship management commercialisation – skills that need to be both developed and recognised. At present no formal career structure exists and in some countries the administrative career structures within PROs restricts their ability to recruit and retain experienced and skilled staff.

At institutional level, while funding systems across Europe varies considerably country to country, they are directed at funding teaching and research only. There are no PRO funding systems with a well-defined funding steam for knowledge exchange (the UK probably comes closest to having such a system).

Therefore to support and encourage knowledge exchange public policy needs to:

259. **Ensure that the knowledge exchange (or 'third') mission is embedded in PRO institutional strategies.** Responsibility for knowledge exchange should lie at vice-rector level and be aligned with institutions' research and education missions

260. **Ensure that a funding stream for knowledge exchange is made available** to support the required third mission and that the route for accessing such funding is clearly articulated and communicated to PROs. No one funding method suits all jurisdictions but the route to funding should be clear. As the immediate financial benefits of knowledge exchange (i.e. licence income) tend to be lower than the costs the temptation, in an era of budget cuts, to decrease in funding for knowledge exchange should be avoided since the overall benefit to society is much larger.

261. **Recognise and reward academics for knowledge exchange activities.** Academic researchers are essential for knowledge exchange but not all academics 'buy-in' to the concept that knowledge exchange is a key function of their role. Cultural change among the academic community is a slow process and establishing a strong knowledge exchange culture in European PROs will take time. However this is unlikely to be achieved unless knowledge exchange becomes a key part of academic reward and recognition systems.

262. **Ensure that knowledge exchange activity and outputs are appropriately monitored and measured.** Measurement tends to drive behaviour and therefore a strong monitoring system will serve to encourage and embed knowledge exchange activities. In the longer-term this might result in aligning knowledge exchange outputs with performance-based PRO funding systems.

What to do	How to do it	Who should do it
Embed knowledge exchange/ third missions in PRO strategies	Address in the suggested Communication (above), which is intended to influence Member State legislation and behaviour	DG-Research and DG-Education and Culture
Provide a funding stream for knowledge exchange	Address in the suggested Communication	DG-Research and DG-Education and Culture
Reward academics for knowledge exchange	Address in the suggested Communication	DG-Research and DG-Education and Culture
Monitor knowledge exchange	Give this task to the suggested	DG-Research and DG-Education

activity and outputs	Observatory	and Culture

Policy Options

E. Incorporate Advice on Changing Academic Career Structures in Commission Communications on Higher Education

The Commission as a catalytic actor in the higher education arena is able to influence HEIs (in particular) and therefore future Commission Communications on higher education should include recommendations on need for academic reward and recognition systems to encompass the three institutional missions – education, research and knowledge exchange. The European Charter for Researchers could also be amended accordingly. Furthermore the Commission could fund activities to identify and disseminate good practice in academic career structures at both institutional and national levels.

Similarly processes to assess and assure HEI quality should encompass the three missions and be used not only to accredit institutions but could also be used to inform funding allocations – as part of a funding process that balances core, competitive and performance-based allocations.

What to do	How to do it	Who should do it
Provide advice to Member States and PROs on modifying researcher reward systems to promote knowledge exchange	Extend DG-EAC networking and bench-learning activities to encompass knowledge exchange. Incorporate advice in future Communications.	DG-Education and Culture
Change researcher incentive systems	Amend the EC Charter for Researchers	DG-Research

F. Coordinate and Promote the Development of a Professional Career Structures for KTO Staff

A number of processes are underway to develop and accredit a career structure for KTO staff and provide accredited continuing professional development at both national level (e.g. IKT in the UK), European (ASTP, ProTon, EuKTS) and international level (Alliance of Technology Transfer Professionals, ATTP). EuKTS, an OMC Net activity under Framework 7, is developing an accreditation system for KT; it comes to an end in March 2012 and the Commission needs to ensure that its outputs are promoted and disseminated widely.

What to do	How to do it	Who should do it
Encourage professionalisation of training for knowledge exchange	Monitor and encourage adoption of results of EuKTS	DG-Research

G. Monitor and Measure European Knowledge Exchange

Measurement of knowledge exchange is currently too heavily focused on metrics that assess the exploitation of IP (patents filed/ granted, licence agreements and income, spin-outs etc.) and furthermore very little data is collected at a European level. Collecting statistics not only allows monitoring and analysis but also establishes a subject as important. To both disseminate good practice in knowledge exchange metrics and improve information on European knowledge exchange between PROs and industry (and other users), the Commission could initiate a regular survey of PROs to collect data on activities and outputs. This should build on the experience developed in a number of early adopter countries (such as the UK and the Netherlands) in terms of a broader set of metrics and in implementing regular surveys to collect them. It should aim to reach a significant proportion of the broad range of European PROs across all Members States. The data could contribute to the proposed U-Multirank[84] tool for ranking European higher education institutes to provide a more comprehensive assessment of performance and perhaps the innovation scoreboard.

What to do	How to do it	Who should do it
Establish a European Knowledge Exchange Observatory (as described above)	Build or extend an EU-wide data collection and analysis network, with an associated benchmarking and training function.	DG-Research and DG-Education and Culture in cooperation should fund a network to do this

Increased Knowledge Transfer via Horizon 2020

The EU has supported pro-active knowledge exchange for many years through the Framework Programmes, and Horizon 2020 in the future. The FP collaborative R&D instrument is one of few mechanisms to support truly cross-European partnerships between PROs and businesses and, along with its support for innovation networking, has contributed to improving the European innovation system. However industrial participation has been declining in the Framework Programmes, falling from 39% in FP4 to 31% in FP6 and accounting for 25% at the mid-point of FP7.[85] For knowledge transfer to occur PROs and businesses need to interact and any decline in industrial participation is a concern. The decline needs to be reversed in Horizon 2020 through allocating sufficient funding to collaborative instruments (the focus on excellence science and a greater emphasis on 'close to market' activities[86] should not be at the expense of collaborative activities) and more importantly, simplifying the financial rules and processes and harmonising their implementation.

[84] The tool already includes some KT metrics but could be improved based on a review of the most appropriate metrics

[85] Interim Evaluation of the Seventh Framework Programme, Report of the Expert Group, November 2010

[86] EC, Factsheet on Industrial participation in Horizon2020, 30 November 2011, http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=press#other

Furthermore, the importance of publications to knowledge exchange should not be ignored and open access to the outputs of publicly funded research should be considered the default position. Therefore the Commission's policy initiatives in open access, started under FP7, and its statements in support of open access in Horizon 2020 documentation,[87] should be fully supported by the Parliament.

Policy Options

H. Monitor and Review Industrial Participation in Horizon 2020

The Parliament needs to monitor and review participation to ensure that all possible measures are being taken to increase industrial participation in Horizon 2020.

What to do	How to do it	Who should do it
Encourage increased industrial participation in the Framework Programme	Continue to pursue the Commission's simplification efforts in developing Horizon 2020	DG-Research, DG-Infso (soon to be DG Connect)

I. Open Access to Horizon 2020 Research Outputs

Publications are an important knowledge exchange mechanism for industry, but academic publications remain beyond the use of many businesses behind the firewalls of academic publishers. For publicly funded research outputs there is a strong argument that this should not be the case and that an open access approach to publication is more appropriate. Open access features in the current proposed Regulation of the European Parliament and of the Council 'laying down the rules for the participation and dissemination in 'Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020)'[88] and it should be endorsed by the Parliament.

What to do	How to do it	Who should do it
Encourage Open Access	Support RC policy initiatives on Open Access	European Parliament

[87] COM(2011) 808 final; COM(2011) 810 final 2011/0399 (COD), November 2011

[88] COM(2011) 810 final 2011/0399 (COD), November 2011

Appendix A Glossary

Figure 23 Glossary of terms

Acronym	Full title
ASTP	Association of European Science and Technology Transfer Professional
AUTM	Association of University Technology Managers (USA)
CPD & CE	Continuing Professional Development & Continuing Education
EIT	European Institute of Innovation and Technology
HEI	Higher Education Institute
KIC	Knowledge and Innovation Community
KT	Knowledge Transfer
KTO	Knowledge Transfer Office
PRO	Public Research Organisation (i.e. universities, other higher education institutes and public research institutes)
RTO	Research and Technology Organisation
TTO	Technology Transfer Office

Appendix B Research Questions and Case Study Sample

B.1 Research questions

1. What are the main mechanisms of knowledge transfer from PROs to industry, and how do they work?
2. What can be said about their relative effectiveness?
3. What do they actually transfer?
4. How does this have effects?
5. Are the transfer mechanisms alternatives or do they act in a complementary way?
6. Which mechanisms are best for which 'innovation models'?
7. What can therefore be said about attributing effects to individual transfer mechanisms?
8. How can we characterise the innovation models used in different industries and technologies, in relation to their use of external knowledge sources? This includes the question of how major company users of basic and applied research tackle the use of external knowledge in their innovation strategies.
9. What is the distinctive role of TTOs in knowledge transfer?
10. In theory (especially economic theory)
11. In different industries
12. In different areas of science and technology
13. In 'superuniversities' (like Cambridge, Harvard, etc with global reach); in nationally orientated research-performing universities; in regional universities; and in research institutes
14. What is the role of TTOs within PROs? How does this affect PROs' strategies in terms of the proportion of transferable technology they produce, compares with other outputs such as basic research and education?
15. What is the US and European experience of the costs and benefits of operating TTOs
16. What can be said about the direct cost and income effects?
17. What can be said about the wider economic impacts?
18. What distinctively European barriers are there to the implementation of TTOs in PROs and their effective operation?
19. What is the pattern of diffusion of 'good TTO practice', as defined by the profession itself, in Europe today?
20. What policy instruments are available to refine and diffuse such good practice?
21. What are the policy opportunities for improving the transfer of knowledge from PROs to industry?
22. Using TTOs, via diffusing 'good practice'

23. By developing more segmented TTO strategies and coupling these to other mechanisms that promote the transfer of knowledge from PROs to industry

24. Through policies and support instruments developed at European, national and regional levels

25. By adjusting the balance of effort between TTOs and other ways to promote the transfer of knowledge from PROs to industry

26. What policy changes are needed at European, national and regional levels?

B.2 Case study sample

PRO	Country	PRO Group *	National Innovation Group *	PRO Coverage/focus
University Libre Bruxelles	BE	1	B	Broad coverage
Lund University	SE	1	A	Broad coverage
University of Aarhus	DK	1	B	Broad coverage
University of Oxford	UK	1	B	Broad coverage
University of Sussex	UK	1	B	Broad coverage
Delft University of Technology	NL	1	B	Technology
Swiss Federal Institute of Technology Zurich (ETH Zurich)	CH	1	A	Technology
CNRS	FR	2	B	Broad coverage
Fraunhofer	DE	2	B	Applied Science
University of Milan	IT	3	C	Broad coverage
University of Barcelona	ES	3	C	Broad coverage
University of Tuebingen	DE	3	B	Natural sciences
Norwegian University of Science & Technology	NO	3	B	Technology
University College Dublin	IE	3	B	Broad coverage
Université de Technologie de Compiègne	FR	4	B	Technology
Maribor University	SL	4	D	Broad coverage
University of Debrecen	HU	4	C	Broad coverage (with strong focus on medicine)
University of Hertfordshire	UK	4	B	Broad coverage
Mayasark University	CZ	4	C	Broad coverage
University of North Carolina	USA	6	A	Broad coverage (with strong focus on medicine)
MIT	USA	6	A	Technology
Colorado University	USA	6	A	Broad coverage

***Definitions:**

UNIVERSITY TYPE	
Group	**Description**
1	Top 50 European research intensive universities (based on the THES/2011-2012) and/or top patent performers
2	Top European non-university research performers
3	Medium-high ranking universities (50-150 in THES rankings); lower patent performance
4	Less-research intensive universities/ PROs
5	PROs in the USA

COUNTRY INNOVATION PERFORMANCE	
Group	**Description (based on PRO-INNO typology of country innovation)**
A	Finland, Sweden, Switzerland, Japan, the USA, Singapore and Israel are the global innovation leaders.
B	The group of next-best performers includes Germany, Denmark, Netherlands, Canada, the UK, Republic of Korea, France, Iceland, Norway, Belgium, Australia, Austria, Ireland, Luxembourg and New Zealand.
C	The group of follower countries includes the Hong Kong, Russian Federation, Slovenia, Italy, Spain, Czech Republic, Croatia, Estonia, Hungary and Malta.
D	The group of lagging countries includes Lithuania, Greece, China, Slovakia, South Africa, Portugal, Bulgaria, Turkey, Brazil, Latvia, Mexico, Poland, Argentina, India, Cyprus and Romania.

Appendix C Importance of Different KT mechanisms

C.1 Evidence from the industry perspective

A very limited number of studies have addressed the role of PROs from the industry, or demand, perspective with the most notable being by Cohen et al (2002) and Bekkers (2008).[89]

The Cohen study supports the view that PROs are relatively low in importance as a source of inputs to business R&D than other sources such as customers and in-house sources. Interestingly the study also showed that public research is used to a slightly larger extent to address existing problems and needs than to suggest new areas for research efforts, which the authors suggests is in line with a more interactive and inter-connected model of the innovation process**.**

The two studies use different categories for knowledge transfer mechanisms and so, for comparison, a mapping has been made, based on the information available, of the mechanisms used against in the studies against the mechanisms defined in section 53.1. Furthermore as different assessment methods have been used it is only possible to compare each mechanism in terms of its relative positions in the ranking of importance.

Despite using different categories for the knowledge transfer mechanisms the pattern of relative importance is rather similar. For Cohen the most frequently cited mechanisms are the traditional channels of open science - publications and reports, followed by informal interactions and meetings/conferences. Patents and licences (separate categories in the study) were ranked 7th and 9th respectively out of ten mechanisms (Figure 25). While Bekkers used much longer list of 23 knowledge transfer mechanisms, publications, in various forms, still feature at the top of the ranking for industry, followed by a large group of mechanisms that include access to graduates (at all levels up to PhD), informal and formal collaborations and contract R&D and consultancy. Similar to Cohen exploiting PRO-generated IP ranks relatively low.

It should be noted that both studies selected their industrial samples from businesses with an R&D function; Cohen selected from the broadly defined 'manufacturing sector' while Bekkers sample of industry was a little more skewed towards those businesses within sectors that might be considered to be science-based (pharmaceuticals, chemicals and electrical and communications equipment) but it also included the less high-tech or science based sector - machinery, basic and fabricated metal products and mechanics. Nevertheless both studies show that even amongst a group of businesses in industries that might be expected to be able to interact fairly readily with PROs, there is a widespread use of different knowledge transfer mechanisms with a relatively high use of publications and a relatively low use of formal IP.

[89] Cohen at al. op.cit. (2002); Bekkers et al, op. cit. (2008)

Figure 24 Relative importance of KT mechanisms: Industry (Bekkers et al, based on table 1)

Industry ranking	KT Mechanism (Bekkers)	Correspondence to Knowledge transfer mechanisms defined in Figure 3	Cited as high importance by % of industry respondents
1	Other publications, including professional publications and reports	Publications	82%
2	Scientific publications in (refereed) journals / books	Publications	76%
3	Personal (informal) contacts	Informal collaboration	73%
4	Patent texts, as found in the patent office or in patent databases	Other (a form of publication)	71%
5	University graduates as employees (B.Sc/M.Sc)	Access to research skills	69%
6	Participation in conferences and workshops	Informal collaboration	67%
7	Students working as trainees	Access to research skills	63%
8	University graduates as employees (Ph.D. level)	Access to research skills	62%
9	Joint R&D projects (except those in the context of EU Framework Programmes)	Formal collaboration	60%
10	Joint R&D projects in the context of EU Framework Programmes	Formal collaboration	49%
11	Contract research (excl. Ph.D. projects)	Contract R&D and consultancy	44%
12	Financing of Ph.D. projects	Access to research skills	37%
13	Staff holding positions in both a university and a business	Access to research skills	36%
15	Consultancy by university staff members	Contract R&D and consultancy	35%
15	Flow of university staff members to industry positions (exc. Ph.D. graduates)	Access to research skills	35%
16	Sharing facilities (e.g. laboratories, equipment, housing with universities)	Other	33%
18	Licenses of university-held patents and 'know-how' licenses	Exploiting IP	32%
18	Personal contacts via membership of professional organisations	Informal collaboration	32%
18	University spin-offs (as a source of knowledge)	Exploiting IP	32%
20	Temporary staff exchange (e.g. staff mobility programmes)	Access to research skills	27%
21	Specific knowledge transfer activities organised by the university's TTO	Other	15%
22	Contract-based in-business education & training	Other	14%
23	Personal contacts via alumni organisations	Informal collaboration	10%

Figure 25 Relative importance of KT mechanisms: Industry (Cohen et al, based on table 4)

Industry ranking	Knowledge transfer mechanism (Cohen)	Correspondence to Knowledge transfer mechanisms defined in Figure 3	Cited as important by % of industry respondents
1	Publications and reports	Publications	42%
2	Informal interactions	Informal collaboration	36%
3	Meetings or conferences	Informal collaboration	35%
4	Consulting	Contract R&D & consultancy	32%
5	Contract research	Contract R&D & consultancy	21%
6	Recent hires	Accessing research skills	20%
7	Patents	Exploiting IP	18%
8	Cooperative/joint ventures	Formal collaboration	18%
9	Licences	Exploiting IP	10%
10	Personnel exchange	Accessing research skills	6%

C.2 Evidence from the PRO perspective

As for the industry perspective the categories of knowledge transfer mechanisms used in studies from the PRO perspective are not the same across the studies and so the same mapping was made, based on the information available, of the mechanisms defined in **Figure 3**.

The Bekkers' study looked at the importance of different knowledge transfer mechanisms from both the industry and PRO perspective and found very little difference between the two (Figure 24 and Figure 26). Eight of the top ten most important mechanisms are the same for both industry and PROs, and include publications, informal interactions and accessing research skills. For both industry and PROs contract R&D and consultancy fall in the middle ground while exploiting IP is of less importance – albeit slightly more important for industry than PROs.

Studies by Agrawal and Martinelli[90] addressed specific universities, namely the University of Sussex in the UK and MIT in the USA respectively, with the former gathering data across all academic faculties and the latter addressing a much narrower range of two engineering departments. Publications are ranked highly for the MIT study (publications were not addressed by the Sussex study) but interestingly, rank below consulting, which received the highest ranking. This may be the result of the national and organisational context for MIT i.e. a private university in the USA with a strong tradition (borne out of necessity to some extent) of attracting private funding. For MIT, exploiting IP ranks relatively low but higher than the informal mechanisms. The Sussex study contains a much smaller set of mechanisms and makes a slightly different assessment – the frequency of use rather than their importance. The findings rank consultancy higher than informal routes and access to skills, and exploiting IP is ranked very low in terms of usage.

[90] Martinelli et al, op. cit. (2008); Ajay Agrawal et al, op. cit. (2002)

The KT case studies present a similar picture. The interviewees able to make an assessment of the relative importance of the different KT mechanisms[91] reported a mixed picture with impacts arising from all mechanisms in varying degrees. Publications were generally reported as more important for disciplinary progress and for wider benefits in the shorter term while mechanisms such as collaborative and contract R&D, consultancy and IP exploitation as more important for supporting wider benefits in the longer term.

From both a business and PRO perspective the most important mechanisms for accessing public research appear to be the public and personal channels such as publications, conferences, and informal interactions, rather than the more formal channels of collaborations and IP. This is not to suggest that exploiting IP generated by PROs is not important, but that it needs to be seen in a wider context.

In practice, TTOs report, individual companies with fairly intensive interactions with PROs make use of a range of KT mechanisms; using different mechanisms to instigate and then develop long-term relationships with relevant academics and research groups to access relevant knowledge and expertise. Publications, for example, may help identify the key players in a field, or a relationship might start with a consultancy or contract R&D project to solve a particular relatively short-term problem. Opportunities for Collaborative R&D may arise as a deeper understanding is gained of each others' skills, needs and motivations and a level of trust has been developed, and such projects might result in IP that the industry partner can exploit.

Licencees of PRO-generated IP tend to be organisations already known to the PRO[92] and are, therefore the culmination of longer-term relationships. Interestingly, empirical research suggests that IP licensing can also be the starting point for a relationship; here patents are used to identify who to work with (e.g. through patent scanning) and licensing is used as a method to instigate and then develop relationships with academics.[93] Furthermore, the exploitation of PRO generated IP, which is typically at a very early stage of development, usually requires further input from academic researchers during the development and (if successful) eventual commercialisation phases. This can take the form of collaborative R&D, contract R&D or consultancy that facilitate the transfer of 'the softer' forms of knowledge such as tacit knowledge and know-how.

[91] As individuals, with a relatively narrow view point, most felt unable to make this assessment

[92] *Inventor's Guide to Tech Transfer outlines the essential elements of technology transfer at the Massachusetts Institute of Technology*. Technology Licensing Office, MIT, 2005

[93] Ahmad Rahal, *University technology buyers, a glimpse into their thoughts*, Journal of Technology Management and Innovation, Vol. 3, Issues 1, pp 38-41, 208; and Gillian McFadzean, *A comparison of different exploitation methods (eg licensing, selling, spin-outs) as means to extract value from research results: why do people or organisations choose certain routes for the exploitation of research results*, European Commission 2009 Expert Group on Knowledge Transfer (2009)

Figure 26 Relative importance of KT mechanisms: PRO (Bekkers et al, based on table 1)

Uni rank	KT Mechanism (Bekkers)	Correspondence to Knowledge transfer mechanisms defined in Figure 3	Cited as high importance by % of university respondents
1	Personal (informal) contacts	Informal collaboration	91%
2	Scientific publications in (refereed) journals / books	Publications	90%
3	Participation in conferences and workshops	Informal collaboration	89%
4	University graduates as employees (Ph.D. level)	Access to research skills	89%
5	Other publications, including professional publications and reports	Publications	81%
6	Joint R&D projects (except those in the context of EU Framework Programmes)	Formal collaboration	80%
7	University graduates as employees (B.Sc/ M.Sc)	Access to research skills	77%
8	Financing of Ph.D. projects	Access to research skills	76%
9	Students working as trainees	Access to research skills	63%
10	Staff holding positions in both a university and a business	Access to research skills	63%
11	Joint R&D projects in the context of EU Framework Programmes	Formal collaboration	60%
12	Contract research (excl. Ph.D. projects)	Contract R&D and consultancy	55%
13	Consultancy by university staff members	Contract R&D and consultancy	55%
15	Flow of university staff members to industry positions (exc. Ph.D. graduates)	Access to research skills	47%
15	University spin-offs (as a source of knowledge)	Exploiting IP	47%
16	Sharing facilities (e.g. laboratories, equipment, housing with universities)	Other	44%
18	Temporary staff exchange (e.g. staff mobility programmes)	Access to research skills	43%
18	Personal contacts via membership of professional organisations	Informal collaboration	41%
18	Patent texts, as found in the patent office or in patent databases	Other	38%
20	Contract-based in-business education & training	Other	36%
21	Licenses of university-held patents and 'know-how' licenses	Exploiting IP	33%
22	Specific knowledge transfer activities organised by the university's TTO	Other	26%
23	Personal contacts via alumni organisations	Informal collaboration	23%

Figure 27 Frequency of KT mechanisms: PRO (Agrawal, based on table 3)

Uni rank	Knowledge transfer mechanism (Agrawal)	Correspondence to Knowledge transfer mechanisms defined in Figure 3	Relative perceived importance of KT mechanisms (% of total)*
1	Consulting	Contract R&D and consultancy	25%
2	Publications	Publications	19%
3	Recruiting /hiring	Access to research skills	17%
4	Research collaborations	Formal collaboration	12%
5	Co-supervising	Access to research skills / Formal collaboration	9%
6	Patents and licences	Exploiting IP	7%
7	Conversations	Informal collaboration	6%
8	Conferences	Informal collaboration	5%

*The figures sum to more than 100%, however it is the ranking that is of most interest here

Figure 28 Frequency of KT mechanisms: PRO (Martinelli et al, based on table 3)

Uni rank	Knowledge transfer mechanism (Martinelli)	Correspondence to Knowledge transfer mechanisms defined in Figure 3	Proportion of all external links
1	Consultancy	Contract R&D and consultancy	28%
2	Collaborative research	Formal collaboration	26%
3	Research grant*	N/a	24%
4	Research students	Access to research skills	12%
5	Research contract	Contract R&D and consultancy	7%
6	Patents	Exploiting IP	2%
7	Knowledge Transfer scheme#	Access to research skills	1%

N.B. the category of publications was not included in this study

* 'Research grant' refers to funding from an external government or charitable funding body and defined by the academic therefore it is not treated here as a knowledge transfer mechanism.

A specific form of KT support in the UK that links universities to business via a graduate student for two years

Appendix D Taxonomy of Innovation Policies

There are several ways to categorise innovation policies, the examples given here are from two sources: Manchester Institute of Innovation Research at the University of Manchester[94] and Trendchart[95]

Manchester Institute of Innovation Research

Figure 29 Supply side

Policy Objectives and Sub-objectives			Topic / Report	
Improving RDI investment and capabilities of firms and systems **Supply**	increasing financial investment in RDI		Direct Measures (grants, including investment grants, loans, etc.)	
			In-direct (tax allowances, tax credits)	
			Access to capital	Guarantee schemes
				Venture Capital (various schemes)
			Entrepreneurship schemes	Financial measures to create firms (various combinations)
	increasing non-financial capability	skills in firms		Non financial measures to support firm creation (e.g. incubators, science parks)
			Training schemes to improve innovation capabilities in firms	
			Employing people	specific migration schemes
				policies to employ skilled labour
		access to expertise		inter-sectoral mobility schemes
			Schemes for R&D collaboration	
			Supporting transfer of codified knowledge	
			Support for innovation management / advisory service: Awareness and outreach; technical assistance and advice; brokerage and referral; voucher programs; mentoring and coaching	
	increasing systemic capabilities, exploiting complementarities		Clusters policies	
			Innovation networks (sectoral, technologies, geographically spread)	

[94] Jakob Edler, *Evidence-based innovation policy? Merits, limits and challenges of policy analysis*, Presentation to the ESF / STOA conference on "Science of Innovation, Februaty 2012

[95] Trends and Challenges in Demand- Side Innovation Policies in Europe : Thematic Report 2011 under Specific Contract for the Integration of INNO Policy TrendChart with ERAWATCH (2011- 2012), October 2011

Figure 30 Demand side

<table>
<tr><th colspan="2">Policy Objectives and Sub-objectives</th><th colspan="2">Topic / Report</th></tr>
<tr><td rowspan="10">improving innovation climate and context - not directed at firm firms innovation activity directly

<u>demand/ framework</u></td><td rowspan="3">Improving, increasing and enhancing the demand for innovation</td><td colspan="2">Public Procurement (including PCP)</td></tr>
<tr><td rowspan="2">Private awareness and readiness to buy innovation</td><td>Fiscal incentives demand</td></tr>
<tr><td>Awareness and information campaign (public), demonstration projects, (innovation prizes)</td></tr>
<tr><td rowspan="2">Deliberate lead market and market transformation by enhancing supply of and diffusion of innovation</td><td colspan="2">Demand policy mixes explicitly geared at diffusion of innovation</td></tr>
<tr><td colspan="2">Lead Market type initiatives</td></tr>
<tr><td rowspan="2">Improving the framework conditions for innovation</td><td colspan="2">Standardisation</td></tr>
<tr><td colspan="2"><u>Impact of regulation on innovation</u></td></tr>
<tr><td rowspan="3">Targeted discourse</td><td colspan="2">Technology assessment and anticipation of innovation pathways</td></tr>
<tr><td rowspan="2">Platforms</td><td>Technology Platforms</td></tr>
<tr><td>Innovation Platforms</td></tr>
</table>

Trendchart - Categorisation of demand-side policies

Demand-side innovation policy tool	Short description
Public procurement	
Public procurement of innovation	Public procurement of innovative goods and services relies on inducing innovation by specifying levels of performance or functionality that are not achievable with 'off-the-shelf' solutions and hence require an innovation to meet the demand.
Pre-commercial public procurement	Pre-commercial procurement is an approach for procuring R&D services, which enables public procurers to share the risks and benefits of designing, prototyping and testing new products and services with he suppliers
Regulation	
Use of regulations	Use of regulation for innovation purposes is when governments collaborate broadly with industry and non-government organisations to formulate a new regulation that is formed to encourage a certain innovative behaviour.
Standardisation	Standardisation is a voluntary cooperation among industry, consumers, public authorities and other interested parties for the development of technical specifications based on consensus and can be an important enabler of innovation.
Supporting private demand	
Tax incentives	Tax incentives can increase the demand for novelties and innovation by offering reductions on specific purchases.
Catalytic procurement	Catalytic procurement involves the combination of private demand measures with public procurement where the needs of private buyers are systemically ascertained. The government acts here as 'ice-breaker' in order to mobilise private demand.
Awareness raising campaigns, labelling	Awareness raising actions supporting private demand have the role to bridge the information gap consumers of innovation have about the security and the quality of a novelty.
Systemic policies	
Lead market initiatives	Lead market initiatives support the emergence of lead markets. A lead market is the market of a product or service in a given geographical area, where the diffusion process of an internationally successful innovation (technological or non-technological) first took off and is sustained and expanded through a wide range of different services.

Appendix E Analysis of Patenting Patterns of European PROs

E.1 Where do European PROs patent?

There are few consistent data about where and in what fields PROs patent in Europe and most of those that exist tend to give partial, national pictures.

Stephan and others used the 1995 survey of doctorate recipients in the USA to explore who patents. They found that field was an important predictor of the number of patent applications a faculty member makes. Those at medical schools were the most likely to do so. People in the physical sciences are also more likely than average to patent, while those in software were less so. Those at institutions with a history of patenting were more likely than others to apply for patents, underlining the importance of organisational learning in obtaining patents.[96]

Analysis of Swedish university patents[97] suggests that there are two types of academic involvement. Many are close to the technology bases of the firms involved, suggesting that the academics have been partners in innovation-related problem solving. These tend to have limited wider technological impacts because they relate to solving particular problems. Others are technologically more marginal to the firms involved, potentially representing a more radical change or extension of their technology and usually having higher potential technological impacts.

Another key determinant is the technological, or scientific field and its relevance to the industry. Empirical studies have found that the surge in the commercialisation of inventions in the areas of biomedicine and computer software by Columbia University was influenced by the industry's interest in the specific fields[98]. This is also true for the areas of medicine, engineering and sciences, producing most invention disclosures and executing a higher number of licences than other departments of research universities[99]. At the end of the 1980s, universities in the USA were patenting in drugs and medicines (35%), Chemicals (20-25%), electronics (20-25%) and mechanical technologies (10-15%)[100].

The importance of biotechnology and pharmaceuticals has remained a consistent pattern. Three quarters of Belgian university patents in the period 1985-99 were in biotechnology related fields[101]. In Denmark between 1978 and 2003, 51.2% of university patents were taken out in Pharmaceuticals and biotechnology, followed by 17.4% in instruments and then 11.4% in electronics[102].

[96] Paula Sephan, Shiferaw Gurmu, AJ Sumell and Grant Black, "Who's patenting in the university? Evidence from the survey of doctorate recipients," *Economics of Innovation and New Technology*, 61 (2), 2007, 71-99

[97] Daniel Ljungberg and Maureen McKelvey, *Academic involvement in firm patenting: A study of academic patents in Sweden*, Paper presented at the DRUID Summer Conference, 2010 (June)

[98] Mowery *et al.*, op. cit., 1999

[99] Jerry G. Thursby, Richard Jensen and Marie C. Thursby, "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major US Universities," *The Journal of Technology Transfer*, 26 (1-2), 2001, 59-72

[100] Henderson et al, op. cit., 1998

[101] Eleftherios Sapsalis and Bruno van Pottelsberghe de la Potterie, "Insight into the patenting performance of Belgian universities," *Brussels Economic Review*, 46 (3), 2003, 37-58

[102] Lotz et al, op. cit., 2009

In order to analyse the patents of universities by field / technology, we have undertaken a manual search of 'top' universities as patent applicants within the EPO database, downloaded the results of these searches and analysed the results. The methodology is explained in more detail below, with results shown in the following section.

The European Patent Office provides public access to the same patent database that is used by EPO examiners (esp@cenet[103]). The database search function allows you to explore 60 million patent documents (primarily patent applications) from around the world.

Due to the complexity and time-consuming nature of searching the EPO database of patents, a subset of European universities was selected as a sample. Using the two most prominent world university rankings (the Shanghai Jiaotong University Academic Ranking of World Universities 2009[104] and the QS/Times Higher Education World University Rankings 2009[105]) the top ~100 European universities were identified[106]. The resulting list included Universities based in 17 different European countries and most commonly the UK (23), Germany (18), the Netherlands (11) and France (9).

Figure 31 Top ~100 European Universities, by country

Country	Total
UK	23
Germany	18
Netherlands	11
France	9
Switzerland	7
Sweden	6
Belgium	5
Italy	5
Denmark	3
Ireland	2
Norway	2
Russia	2
Austria	1
Finland	1
Greece	1
Spain	1
Grand Total	103

Technopolis, from analysis of the Shanghai Jiaotong University Academic Ranking of World Universities 2009 and the QS/Times Higher Education World University Rankings 2009

[103] http://ep.espacenet.com/advancedSearch?locale=en_EP

[104] http://www.arwu.org/index.jsp

[105] http://www.topuniversities.com/world-university-rankings

[106] The top 80 European universities were taken from each of the rankings, combined and de-duplicated, resulting in a list of 103 Universities

For each sample institution, we first identified a range of possible applicant names that may have been used on patent applications. For instance:

27. The English version of the institutions name (e.g. Ghent University)

28. The 'local' language version of the institutions name (e.g. Gent Universiteit)

29. Any abbreviations / acronyms of the institution name used (e.g. ETH Zurich for the Swiss federal Institute of Technology, Zurich)

30. Holding companies, technology transfer agencies or similar that might make patent applications on behalf of a University (e.g. ISIS innovation for Oxford University) (note that in most cases a Technology Transfer Office exists *within* the University and the University name is therefore used on applications)

For individual institutions there is reasonable consistency between applicants as to the 'applicant name' used, although the naming conventions do vary *between* universities. Undertaking trial searches of the EPO database based on the different naming conventions identified allowed us to ascertain the form (or occasionally forms) used by each university. Where a holding company (or similar) is in place (and especially where this has been established during the 2000-2010 period in question), it was often necessary to search both for the University name and the name of the company/agency dealing with patent applications on behalf of the university (e.g. University of Cambridge patents are split relatively evenly between those where the applicant is named as 'university cambridge' and 'cambr entpr').

The time period was limited to those patents published between 2000 and 2010 (inclusive) and incorrect results were removed manually from the results of the database search.

A full list of sample institutions and their country are shown in Figure 32 below. The final criteria used (based on various trials) to search the database for patent applications by each university are shown in the third column. The final column shows the number of resulting patents found in the database. 13,131 patents were identified in total, representing an average of 128 per university in our sample.

Figure 32 Applicant search criteria and search results (2000-2010), 'top' European Universities

Institution	Country	Search Criteria	Patents found
University of Cambridge	UK	university cambridge [gb] / cambridge entpr [gb]	812
University of Oxford	UK	university oxford [gb] / isis innovation [gb]	1176
University College London	UK	university college london [gb] / UCL business [gb] / UCL biomedia [gb]	396
Swiss Federal Institute of Technology Zurich	Switzerland	ETH Zurich [ch] /Eidgenoess tech hochschule [ch] / ETH transfer [ch]	160
The Imperial College of Science, Technology and Medicine	UK	imperial college [gb] NOT ltd / imp innovations [gb]	931
Pierre and Marie Curie University - Paris 6	France	univ paris curie	266
The University of Manchester	UK	univ manchester [gb]	268
University of Copenhagen	Denmark	univ copenhagen / kobenhavns uni [dk]	61
University of Paris Sud (Paris 11)	France	univ paris sud	127
Karolinska Institute	Sweden	karolinska	89
Utrecht University	Netherlands	univ utrecht / utrecht holding	159
The University of Edinburgh	UK	univ edinburgh	188
University of Zurich	Switzerland	univ zurich / zuercher hochschule	195
University of Munich	Germany	univ muenchen maximilian	102
Technical University Munich	Germany	univ muenchen tech NOT maximilian	171
University of Bristol	UK	univ bristol [gb]	209
University of Heidelberg	Germany	univ heidelberg	130
University of Oslo	Norway	uni oslo / Birkeland Innovasjon	36
King's College London	UK	king london [gb]	173
Ecole Normale Superieure – Paris	France	ecole normale superieure paris NOT cachan	3
University of Helsinki	Finland	helsingin yliopisto	8
Leiden University	Netherlands	leiden univ	58
Uppsala University	Sweden	uppsala university	2
Moscow State University	Russia	Moscow State University [ru]	14
The University of Sheffield	UK	univ sheffield [gb] NOT hallam	241
University of Nottingham	UK	univ nottingham [gb] NOT trent	188
University of Basel	Switzerland	univ basel	75

Stockholm University	Sweden	stockholm university	2
University of Goettingen	Germany	univ Goettingen	83
University of Birmingham	UK	univ birmingham [gb]	87
University of Aarhus	Denmark	aarhus uni	102
University of Bonn	Germany	univ bonn	79
Catholic University of Leuven	Belgium	univ leuven kath	175
Catholic University of Louvain	Belgium	univ louvain	164
Ghent University	Belgium	ghent university / gent universiteit	71
University Libre Bruxelles	Belgium	univ bruxelles	347
University of Paris Diderot (Paris 7)	France	univ paris 7 diderot	55
University of Strasbourg	France	univ strasbourg	104
University of Frankfurt	Germany	univ frankfurt	56
University of Freiburg	Germany	univ freiburg	180
University of Mainz	Germany	univ mainz	91
University of Muenster	Germany	univ muenster	57
University of Tuebingen	Germany	univ tuebingen	250
University of Wuerzburg	Germany	univ wuerzburg	73
University of Milan	Italy	univ milano NOT bico	132
University of Pisa	Italy	uni pisa	60
University of Roma - La Sapienza	Italy	uni roma la sapienza	14
University of Amsterdam	Netherlands	univ amsterdam	94
University of Groningen	Netherlands	univ groningen	85
University of Wageningen	Netherlands	wageningen [nl]	125
VU University Amsterdam	Netherlands	[VU univ amsterdam / vrije univ amsterdam / vu amsterdam]	0
Lund University	Sweden	lund university	13
Swiss Federal Institute of Technology of Lausanne	Switzerland	EPFL lausanne	271
University of Geneva	Switzerland	univ geneve	104
The University of Glasgow	UK	univ glasgow	202
University of Leeds	UK	univ leeds	143
University of Liverpool	UK	univ liverpool	79
University of Sussex	UK	univ sussex	35
University of Vienna	Austria	univ wien NOT tech	19
Technical University of Denmark	Denmark	univ denmark tech dtu	78
Joseph Fourier University (Grenoble 1)	France	joseph fourier univ	185
University of Paris Descartes (Paris 5)	France	univ descartes	93
University of Hamburg	Germany	univ hamburg NOT harburg	40
University of Kiel	Germany	univ kiel	62
University of Koeln	Germany	univ koeln	38
University of Padua	Italy	univ padova	58
Delft University of Technology	Netherlands	univ delft tech / TU Delft	294
Erasmus University	Netherlands	univ erasmus NOT medical	65

Radboud University Nijmegen	Netherlands	univ nijmegen	46
University of Barcelona	Spain	univ barcelona	175
University of Bern	Switzerland	univ bern	71
Cardiff University	UK	univ cardiff	165
Queen Mary, U. of London	UK	queen mary [gb] NOT westfield	9
University of Durham	UK	univ durham [gb]	75
University of East Anglia	UK	univ east anglia	27
University of Leicester	UK	univ leicester	66
University of Southampton	UK	univ southampton [gb]	248
University of St Andrews	UK	univ st andrews [gb]	94
University of Warwick	UK	univ warwick [gb]	109
École Polytechnique	France	ecole polytech [fr]	114
Trinity College Dublin	Ireland	trinity college dublin	176
London School of Economics and Political Science (LSE)	UK	[london shool of economics / LSE]	0
University of YORK	UK	univ york [gb]	123
University College DUBLIN	Ireland	univ college dublin NOT city	115
Free University of Berlin	Germany	freie univ berlin	73
MAASTRICHT University	Netherlands	univ maastricht	44
EINDHOVEN University of Technology	Netherlands	eindhoven univ tech	98
Ecole Normale Superieure de Lyon	France	ecole norm superieure lyon	31
University of ABERDEEN	UK	univ aberdeen	121
University of BERGEN	Norway	uni bergen / bergen teknologieverforing	4
University of BATH	UK	univ bath [gb]	78
Humboldt University of Berlin	Germany	univ humboldt	70
NEWCASTLE University	UK	univ newcastle [gb]	108
LANCASTER University	UK	univ lancaster [gb]	25
Saint-Petersburg State University	Russia	st petersburg state	3
University of LAUSANNE	Switzerland	univ lausanne NOT polytec	82
University of BOLOGNA	Italy	univ bologna	90
KTH ROYAL INSTITUTE of Technology	Sweden	[KTH]	0
University of ANTWERP	Belgium	univ antwerp	10
University of ATHENS	Greece	univ athens [gr]	4
RWTH Aachen University (Rheinisch-Westfälische Technische Hochschule Aachen)	Germany	rwth aachen	91
University of Karlsruhe	Germany	univ karlsruhe NOT forschzent	85
University of GOTHENBURG	Sweden	[goeteborgs / goteborgs holdingbolaget]	0
Total			**13,131**

Patent applications and documents are categorised in hierarchical classification systems according to their technical content, using the International Patent Classification (IPC) system. The IPC has a hierarchical structure and is subdivided into sections (and sub-sections), classes, subclasses, groups and subgroups. The highest levels in the hierarchical system are sections and sub-sections, as follows:

31. A – Human Necessities (Agriculture; Foodstuffs and Tobacco; Personal or domestic articles; Health, Life-saving and Amusement; Other)

32. B – Performing Operations; Transporting (Separating and Mixing; Shaping; Printing; Transporting; Micro-structural technology and Nano-technology; Other)

33. C – Chemistry; Metallurgy (Chemistry; Metallurgy; Combinatorial technology; Other)

34. D – Textiles; Paper (Textiles or flexible materials not otherwise provided for; Paper; Other)

35. E – Fixed Constructions (Building; Earth or rock drilling and Mining; Other)

36. F – Mechanical Engineering; Lighting; Heating; Weapons; Blasting Engines or Pumps (Engines or pumps; Engineering in general; Lighting and Heating; Weapons and Blasting; Other)

37. G – Physics (Instruments; Nucleonics; Other)

38. H – Electricity (Electricity; Other)

The IPC currently divides technology into around 70,000 subareas in total, although for our purposes, only sections (e.g. A) and classes (e.g. A47) are necessary.

A maximum of three (often similar) IPC symbols are displayed for each title in the results list. We have taken the first allocation in each case.

The following issues were encountered in undertaking a search of the EPO database of patents:

39. Although it is the intention of EPO that the database should be searched in English, we are aware that other languages have been used in entering information on applicants. The words used in the applicant field are reasonably standardised within an institution, though not across institutions. In most cases, the national language version is used (e.g. Uni padova, rather than uni padua). For each institution we attempted a number of different search criteria to find the naming convention and language used in each case

40. The EPO notes that if a patent was sold to a company, then the inventor (e.g. a University) may not be recorded as the applicant. In such cases, the patent is unlikely to be identified through our search

41. Most patents (95%+) have an IPC code. Where this code is not entered, in most cases a European Classification System code (an extension of the IPC system) was available and used for analysis. In a small number of cases, neither was available and the patent was allocated to an IPC section manually by the study team from the patent title. For most institutions, the necessity to undertake a manual classification was minimal (<5 patents). However, around half of the patents found for Italian Universities did not have an IPC/ECLA code and had to be manually assigned.

42. Information provided separately from the KTH database for patents 2003-8 suggests that in most, if not all, cases the 'applicant' on patents for this University are individuals or companies, rather than the University itself. Given the small number of patents identified across all Swedish Universities, a similar situation is likely to exist in other Universities within this country

The database search resulted in 13,131 patents being identified for the 103 Universities, across the 10-year publication period 2000-2010. The number of patents granted to this sample of universities has tended to grow over time, as shown in Figure 33 below.

Figure 33 Total number of patents granted, 'top' European Universities by year

Year	Count	Percentage
2000	762	5.8%
2001	777	5.9%
2002	972	7.4%
2003	1,080	8.2%
2004	1,182	9.0%
2005	1,146	8.7%
2006	1,211	9.2%
2007	1,326	10.1%
2008	1,367	10.4%
2009	1,714	13.1%
2010	1,596	12.2%
Total	**13,131**	**100.0%**

E.2 Total patents by IPC Section, Sub-Section and Class

A breakdown of total patents by the top-level **IPC sections** is shown in Figure 34 below. The final column shows the proportion of total patents allocated to each of the eight technical fields. It suggests that over half of the patents fall into two categories (Human necessities, and Performing operations & Transporting). Physics account for a further fifth of the total number of patents, while Electricity accounts for 10%.

Figure 34 Total number of patents granted to the 'top' European Universities (2000-2010), by IPC Section

IPC Section	Count	Percentage
A - Human necessities	3,796	28.9%
B – Performing operations; Transporting	937	7.1%
C – Chemistry; Metallurgy	3,869	29.5%
D – Textiles; Paper	41	0.3%
E – Fixed constructions	84	0.6%
F – Mechanical engineering; Lighting; Heating; Weapons; Blasting	213	1.6%
G – Physics	2,861	21.8%
H – Electricity	1,330	10.1%
Total	**13,131**	**100.0%**

Figure 37 below shows a slightly more detailed breakdown, with each of the IPC sections divided into a small number of **sub-sections**. Again, the final column shows the proportion of total patents allocated to each of these (more-detailed) technical fields. Chemistry (28%), Health, Life-saving & Amusement (25%), and Instruments (22%) are the main areas of patent activity.

Figure 35 Total number of patents granted to the 'top' European Universities (2000-2010), by IPC Sub-Section

IPC Section	IPC Sub-Section	Count	Percentage
A	Agriculture	390	3.0%
A	Foodstuffs; Tobacco	116	0.9%
A	Personal Or Domestic Articles	34	0.3%
A	Health; Life-Saving; Amusement	3,256	24.8%
A	Other	-	0.0%
B	Separating; Mixing	523	4.0%
B	Shaping	205	1.6%
B	Printing	32	0.2%
B	Transporting	110	0.8%
B	Micro-Structural Technology; Nano-Technology	67	0.5%
B	Other	-	0.0%
C	Chemistry	3,634	27.7%
C	Metallurgy	214	1.6%
C	Combinatorial Technology	20	0.2%
C	Other	1	0.0%
D	Textiles Or Flexible Materials Not Otherwise Provided For	38	0.3%
D	Paper	3	0.0%
D	Other	-	0.0%
E	Building	68	0.5%
E	Earth Or Rock Drilling; Mining	16	0.1%
E	Other	-	0.0%
F	Engines Or Pumps	85	0.6%
F	Engineering In General	76	0.6%
F	Lighting; Heating	50	0.4%
F	Weapons; Blasting	2	0.0%
F	Other	-	0.0%
G	Instruments	2,834	21.6%
G	Nucleonics	26	0.2%
G	Other	1	0.0%
H	Electricity	1,330	10.1%
H	Other	-	0.0%
Total		**13,131**	**100.0%**

The technical field of patents can be broken down further into **129 classes**. However, patents are heavily concentrated within certain of these classes. In fact, just 13 of the

129 classes contain 100 or more of the 13,131 patents each, and together account for 85% of the total. These classes are listed in Figure 36 below.

Nearly one-quarter of all the patents across the 103 universities fall into the class of Medical or veterinary science & Hygiene. Measuring & Testing, Biochemistry, and Organic Chemistry are the next biggest classes.

Figure 36 Total number of patents granted to the 'top' European Universities (2000-2010), by selected IPC Classes

IPC Class (Code)	IPC Class (Name)	Count	% of total
A61	Medical Or Veterinary Science; Hygiene	3,230	24.6 %
G01	Measuring; Testing	1,773	13.5 %
C12	Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation Or Genetic Engineering	1,660	12.6 %
C07	Organic Chemistry	1,400	10.7 %
H01	Basic Electric Elements	795	6.1%
G06	Computing; Calculating; Counting	488	3.7%
B01	Physical Or Chemical Processes Or Apparatus In General	410	3.1%
A01	Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing	390	3.0%
G02	Optics	313	2.4%
H04	Electric Communication Technique	303	2.3%
C08	Organic Macromolecular Compounds; Their Preparation Or Chemical Working-Up; Compositions Based Thereon	178	1.4%
C01	Inorganic Chemistry	142	1.1%
A23	Foods Or Foodstuffs; Their Treatment, Not Covered By Other Classes	109	0.8%
…	…	…	…
…	…	…	…
Total		**13,131**	**100 %**

A comparison between the most frequent classes of patenting in the early part of the period (2000-2) and the latest part of the period (2008-10) suggest that there has been little change in overall patenting patterns over time.

There have however been some small changes (see table below). For instance, the share of total university patenting accounted for by biochemistry (C12), physical/chemical processes (B01), Agriculture (A01) and Optics (G02) has fallen between the two periods, whilst the share of patents accounted for by basic electric elements (H01), computing (G06), electric communication (H04) and organic macromolecular compounds (C08) has risen between the two periods.

Figure 37 Total number of patents granted in the 'top' IPC classes in 2000-2 and 2008-10

IPC Class	IPC Class (Name)	2000-2002	2008-2010
A61	Medical Or Veterinary Science; Hygiene	24.1%	24.6%
G01	Measuring; Testing	12.9%	13.5%
C12	Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation Or Genetic Engineering	14.1%	12.4%
C07	Organic Chemistry	10.2%	10.8%
H01	Basic Electric Elements	4.8%	6.9%
G06	Computing; Calculating; Counting	3.1%	4.2%
B01	Physical Or Chemical Processes Or Apparatus In General	3.8%	2.3%
A01	Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing	5.2%	2.3%
G02	Optics	3.3%	1.9%
H04	Electric Communication Technique	1.4%	2.5%
C08	Organic Macromolecular Compounds; Their Preparation Or Chemical Working-Up; Compositions Based Thereon	1.0%	1.0%
C01	Inorganic Chemistry	0.8%	1.1%
A23	Foods Or Foodstuffs; Their Treatment, Not Covered By Other Classes	1.0%	0.8%
…	…	…	…
…	…	…	…
Grand Total		**2,511**	**4,677**

E.3 Possible specialisms

E.3.1 Share of an institution's total patents by IPC sub-section

In order to look at whether the overall pattern of patenting varies between institutions and whether any specialisations might exist, we first examined the spread of each individual institution's patents across the various IPC sub-sections. We have excluded those universities with fewer than 20 patents from the analysis (leaving 86 Universities), because small numbers of patents in these cases might suggest a specialism when this is not necessarily the case.

The table below shows those IPC sub-sections (n=10) where at least one of the 86 Universities examined has 10% or more of their patents within this technical category. For each of these sub-sections, the number of universities with 10%+, 20%+, 30%+ and 40%+ of their patents falling within this technical category is shown. For example, 75 of the universities examined have at least 10% of their patents in the health, life-saving and amusement sub-section, and eight of these universities have 40%+ of their patents in this field.

The final column of the table lists those universities with the highest proportion of their own patents falling into this category. For most of the sub-sections this share is between 10% and 20% of an institution's total. However, for four of the categories, the number of universities with 10%+ patents in the field is very large and so only those with 30%+ or 40%+ in the sub-section are listed.

It is important to note that the table does not show the universities with the highest total volumes of patents in a particular field, but those universities whose patents (whatever their total number) are highly concentrated in a particular area. So, for example, although the University of Oxford has the largest number of patents in the electricity sub-section (122 patents), this accounts for only 10% of its total patenting activity, whereas Ghent University has only 29 patents in this category, but this represents 41% of its total patenting activity (and the institution is therefore listed in the table).

Figure 38 IPC sub-sections where universities have a high proportion of their patents within the category

Number of universities with share of their patents in this sub-section being…	>10 %	>20 %	>30 %	>40 %	University 'specialisms'
A - Human Necessities:- Agriculture	4	-	-	-	**>10% =** Free University of Berlin Radboud University Nijmegen University of Wageningen University of Aarhus
A - Human Necessities:- Foodstuffs; Tobacco	1	-	-	-	**>10% =** University of Wageningen
A - Human Necessities:- Health; Life-Saving; Amusement	75	56	30	8	**>40% =** University of Paris Descartes (Paris 5) Utrecht University University of Lausanne University of Aberdeen University of Groningen Leiden University University of Goettingen University College London
B - Performing Operations; Transporting:- Separating; Mixing	8	-	-	-	**>10% =** University of Karlsruhe Humboldt University of Berlin Newcastle University University of St Andrews University of Durham Delft University of Technology Technical University of Denmark Technical University Munich
B - Performing Operations; Transporting:- Shaping	2	-	-	-	**>10% =** RWTH Aachen University University of Warwick
C - Chemistry; Metallurgy:- Chemistry	82	64	36	13	**>40% =** Ecole Normale Superieure de Lyon University of York University of Koeln University of Muenster Radboud University Nijmegen University of Leeds University of Amsterdam University of Mainz University of Strasbourg University of Aarhus University of Bonn University of Copenhagen Karolinska Institute
C - Chemistry; Metallurgy:- Metallurgy	1	-	-	-	**>10% =** University of Oslo
F - Mechanical Engineering; Lighting; Heating; Weapons; Blasting:- Engines Or Pumps	1	-	-	-	**>10% =** Lancaster University
G - Physics:- Instruments	79	40	15	2	**>40% =** Lancaster University University of Sussex
H - Electricity:- Electricity	32	8	2	1	**>30% =** Technical University of Denmark Ghent University

E.3.2 Number of each institution's total patents by IPC section

We then examined the total volume of patents within each institution that were categorised into each IPC section. Figure 39 lists the eight Sections and shows the spread of institutions according to the total number of their patents that fall within that category. So, for example, it shows that one-third of institutions have been 1 and 20 patents in the Human Necessities category, while 58% have more and 9% have none at all.

Figure 39 Proportion of institutions with 'n' patents in each IPC section

	Institutions with 'n' patents in the field					
IPC Section	**n=0**	**1<n<20**	**21<n<50**	**51<n<100**	**101<n**	Total
A - Human Necessities	9%	33%	33%	20%	5%	**103**
B - Performing Operations; Transporting	18%	73%	7%	2%	0%	**103**
C - Chemistry; Metallurgy	6%	32%	46%	13%	4%	**103**
D - Textiles;Paper	85%	15%	0%	0%	0%	**103**
E - Fixed Constructions	72%	28%	0%	0%	0%	**103**
F - Mechanical Engineering; Lighting; Heating; Weapons; Blasting	57%	42%	1%	0%	0%	**103**
G – Physics	8%	50%	31%	9%	3%	**103**
H – Electricity	18%	60%	17%	2%	2%	**103**

For each IPC section we then identified the 10 institutions with the largest number of patents in the category. These 'top-10' lists are shown for each of the eight Sections in the figure below, with the institutional name, country and number of relevant patents indicated.

Figure 40 Top-10 patent holders in each IPC Section

A - Human Necessities	**B - Performing Operations; Transporting**
Imperial College (UK) – 365	University of Cambridge (UK) - 91
University of Oxford (UK) – 293	Delft University of Technology (Netherlands) - 87
University College London (UK) – 182	Imperial College (UK) - 42
University of Cambridge (UK) – 117	University of Oxford (UK) - 35
University Libre Bruxelles (Belgium) - 110	Technical University Munich (Germany) - 34
University of Tuebingen (Germany) - 97	Swiss Federal Institute of Technology, Lausanne (Switzerland) - 26
The University of Manchester (UK) - 91	University of Freiburg (Germany) - 26
Utrecht University (Netherlands) – 91	The University of Sheffield (UK) - 24
University of Zurich (Switzerland) - 90	University of Nottingham (UK) - 21
Pierre and Marie Curie University - Paris 6 (France) – 87	*(Three Universities – 20)*

C - Chemistry; Metallurgy	D - Textiles; Paper
University of Oxford (UK) – 407	The University of Manchester (UK) - 10
University of Cambridge (UK) – 256	University of Leeds (UK) - 7
Imperial College (UK) – 236	RWTH Aachen University (Germany) - 7
University Libre Bruxelles (Belgium) - 109	University of Oxford (UK) - 4
University College London (UK) – 100	University of Bath (United Kingdom) - 2
Pierre and Marie Curie University - Paris 6 (France) – 94	Eindhoven University of Technology (Netherlands) - 2
University of Tuebingen (Germany) - 86	*(Nine Universities – 1)*
The University of Sheffield (UK) – 73	
University of Zurich (Switzerland) - 73	
University of Barcelona (Spain) – 67	

E - Fixed Constructions	F - Mechanical engineering; Lighting; Heating; Weapons; Blasting
Delft University of Technology (Netherlands) - 11	Imperial College (UK) - 36
Technical University Munich (Germany) - 7	University of Nottingham (UK) - 16
University of ABERDEEN (United Kingdom) - 6	University of Oxford (UK) - 13
RWTH Aachen University (Germany) - 5	University of Cambridge (UK) - 11
University of Southampton (UK) – 5	Delft University of Technology (Netherlands) - 9
Eindhoven University of Technology (Netherlands) – 4	University of Karlsruhe (Germany) - 9
The University of Glasgow (UK) – 4	University of Freiburg (Germany) - 8
Technical University of Denmark (Denmark) - 4	Technical University of Denmark (Denmark) - 7
(Five Universities – 3)	Swiss Federal Institute of Technology, Lausanne (Switzerland) - 7
	University College London (UK) - 7

G – Physics	H - Electricity
University of Oxford (UK) – 299	University of Oxford (UK) - 122
University of Cambridge (UK) – 228	University of Cambridge (UK) - 104
Imperial College (UK) – 185	Swiss Federal Institute of Technology, Lausanne (Switzerland) - 68
University of Southampton (UK) – 95	Imperial College (UK) - 66
Swiss Federal Institute of Technology, Lausanne (Switzerland) – 91	University of Bristol (UK) - 45
University College London (UK) – 78	Delft University of Technology (Netherlands) - 44
The University of Manchester (UK) – 73	Catholic University of Leuven (Belgium) - 44
University Libre Bruxelles (Belgium) - 70	University Libre Bruxelles (Belgium) - 34
The University of Glasgow (UK) – 63	King's College London (UK) - 34
Delft University of Technology (Netherlands) - 62	*(Two Universities – 33)*

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