Conceptual Framework:
Leveraging Public Research for Innovation and Growth

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Introduction

A widely-shared policy goal in both high- and middle-income countries is to increase the commercialization of research findings produced by the public research sector in order to support economic growth. This process can occur in the government sector, but the most common commercialization route is through the transfer of knowledge produced by universities and PROs to private sector businesses.

A diverse range of policies have been implemented in many countries to encourage such knowledge transfer, including the establishment of knowledge transfer offices (KTOs[1]) at universities and PROs with the responsibility to find industrial partners that could benefit from research findings. Other policies include support for open publication or close collaboration between the public research sector and businesses. An important issue is how to evaluate the success of these policies in terms of their economic impacts and their effect on various actors within an innovation system. Possible evaluation methods include both case studies and the collection and analysis of knowledge transfer metrics.

This paper provides a framework for evaluation and for the ongoing country studies and the metrics paper.

1. Evolving role of public research institutions in national innovation systems

The public research sector consists of public universities, publicly-funded research organisations (PROs), and private non-profit universities and research organisations that obtain a substantial share of their research funding from local, regional, national, or supranational[2] publicly-funded organisations.

[1] KTOs were originally called 'Technology transfer offices, or TTOs. The use of 'TTO' has fallen out of favor because much of the knowledge transferred by universities today does not involve technology, for instance the rights to biological tissue or logistics software programs.
[2] Examples of supranational publicly-funded organisations include the European Commission, the United Nations and the OECD.

The public research sector plays an important part in an innovation system, both through providing future employees with advanced training and through research that creates knowledge with immediate or potential commercial value, as in the case of basic research. [3] The latter is predominantly produced by the public research sector, which accounts for approximately three-quarters of all basic research in high-income economies and between 80% and 100% in middle-income countries such as Chile, Russia and China.[4]

In the 1950s, the role of research universities was to focus on basic research while PROs often focused on applied research, frequently through extensive research contracts with businesses.[5] This division in research focus between universities and PROs remains today, although universities have always conducted research with commercial applications. Yet what has changed is a growing appetite by business for university research discoveries that have little immediate commercial value, but high potential value with sufficient follow-on research and development (R&D). This was due to rapidly growing commercial opportunities for science-based products such as ICT from the 1950s, biopharmaceuticals after 1973 and precision instruments from the 1980s. In contrast to the trial-and-error development models in engineering-based sectors such as machinery and in chemistry, progress in the science-based sectors required an understanding of why things work, with greater emphasis on the ‘research’ side of R&D.

Government policy has also played an essential role in encouraging and supporting the ability of firms to commercialize knowledge produced by the public research sector. In the 1950s, Government contracts to businesses supported the commercialization of ICT while the development of the biotechnology and pharmaceutical sectors was supported both through research subsidies to businesses and through changes in patent law that permitted genetic material and other discoveries developed through biotechnology to be patented. The private sector also adapted to the opportunities provided by research with future potential value, as shown by the growth of venture capital.

In the process of knowledge transfer, the public research sector has two main public-good roles that are supported by Government policy. The first is to create trained citizens and the second is to support economic activity, in part through several channels for transferring knowledge to the business sector (see Figure 1). These include the hiring of university graduates by businesses, informal discussions between business staff and university academics, reading the published literature or attending conferences where business managers and academics can mix, collaborative research projects that involve businesses and academics, contracting out research to universities, spin-off firms for commercializing knowledge and licensing university IP to businesses.

[3] The text mostly covers universities and PROs. At times, the term “public research sector” is used to cover both of the above. It must be noted that the exact definition of what falls under “PROs and universities” varies from country to country.
[4] See OECD, Research & Development Statistics. Depending on the country in question, it accounts for about 40 percent (Republic of Korea) to close to 100 percent (Slovakia) of all basic research performed.
[5] The first research university was Humboldt University, founded in Berlin in 1810. Humboldt developed a new model for scientific and technological research in the mid 1850s. The Fraunhofer Society, Germany’s largest PRO, was founded in 1949 to serve the applied research needs of Germany industry.

Knowledge transfer also occurs through many of these channels between public research and governments. In this case, the ‘contracting out’ of research to universities or PROs is often referred to as procurement, with the goal of improving public services or addressing social needs.

The channels for knowledge transfer can be divided into two groups, informal and formal. Informal channels such as reading the literature, hiring experienced staff, or informal discussions do not require the recipient of the knowledge to make a payment to the university via a contract, while ‘formal’ channels are based on a contract with a university (licensing, collaboration and contracting-out).[6] Knowledge can be transferred entirely through informal methods, entirely through formal methods, or through a combination of both methods, for instance when informal discussions lead to a research or collaboration agreement that results in an IP license.

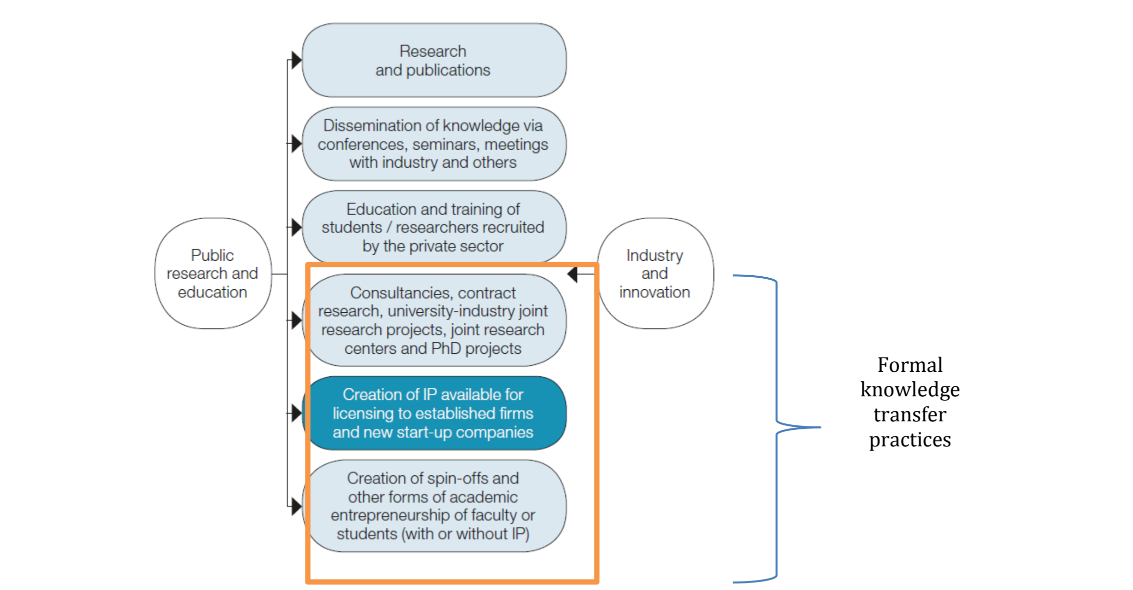
From a public policy perspective, providing information to businesses at no cost will also be beneficial because the greater the number of businesses that use the information, the greater the number of commercial products that will be developed. In addition, competition will reduce costs for consumers. The exception, of course, is when no business will invest in a concept or knowledge without an exclusive license, for instance when the cost to commercialize knowledge is high but the cost for competitors to copy it is low. In this case, it is essential for universities and PROs to be able to grant exclusive licenses to knowledge that it is protected by intellectual property (IP) and consequently from imitation.

Creating the ability to provide exclusive licenses was one of the main purposes of the 1980 Bayh-Dole Act in the United States. It has also led to the widespread adoption of the ‘IP licensing model’ for knowledge transfer, even when an exclusive license is not required. This is partly because universities and PROs are attracted by the potential income from both non-exclusive and exclusive licenses, as well as the need to recover the costs of maintaining a KTO. In addition, the IP licensing model can have other benefits. For instance, some firms, particularly in countries where the leading journals are not available in the national language, could find it easier to search patent databases than the academic literature for sources of ideas for innovation.

Importantly, policies or research that account for only one type of linkage can only provide a partial understanding of the patterns of interaction between the public research sector and businesses and their interdependent nature.

[6] See Foray and Lissoni (2010), but there are grey areas. Hiring university graduates is one of the most important channels from the perspective of businesses, but it is arguably not a formal channel because it does not require a contract with a university. Conversely, hiring academics for a limited period of time, such as in a personnel exchange, can require a contract between a business and a university.

Figure 1: Knowledge transfer channels between the public research sector and businesses



2. The role of policies and practices in promoting knowledge transfer

Relevant policies and practices to support knowledge transfer occur at both the national and institutional level.

A review of existing mechanisms reveals a few important lessons.[7] First, despite the general trend towards institutional ownership and commercialization of university and PRO inventions, a diversity of legal and policy approaches persists, both in terms of how such legislation is anchored in broader innovation policy as well as the specific rules on the scope of university patenting, invention disclosure, incentives for researchers (such as royalty sharing) and whether certain safeguards are instituted to counteract the potentially negative effects of patenting. Second, the means to implement such legislation, as well as the available complementary policies to enhance the impact of public R&D and to promote academic entrepreneurship, vary widely.

National

At the national level, the positive impacts of knowledge transfer primarily depend on both factors that affect the supply of knowledge produced by universities and PROs and factors that affect the demand by firms (and governments) for new knowledge. Supply factors include 1) the quality of new knowledge of relevance to industry and societal challenges and 2) a critical mass of new knowledge such that it can support ongoing investment by either government or firms. Factors influencing the demand for new knowledge by firms and governments include 1) research capabilities and human capital, 2) the legal and regulatory framework, 3) access to finance, 4) the absorptive capacity of firms and governments and 5) potential market or societal demand for innovations.

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[7] WIPO (2011).

The most common national policy of direct relevance to knowledge transfer concerns who owns IP developed in the public research sector. In some countries national laws give ownership to the institution (the university or PRO), other countries assign ownership to the inventor (Sweden), while other countries leave the decision to the institution (Canada).

Institutional policies and practices

At the institutional level, a sizeable amount of literature exists on institutional characteristics that are linked to successful knowledge transfer by KTOs, but there is only limited research on the effect of institutional practices.[8]

Relevant institutional characteristics include:
- The location of the university in a dynamic region near innovative firms, venture capital, etc.;
- The size and type of the university: private universities with a commercial orientation can be more active than public universities
- the portfolio of disciplines, some of which are more prone to knowledge transfer, such as biomedical research;
- The research quality of the institution, its reputation and network;
- the extent of existing collaboration with a university and its entrepreneurial climate;
- The number of KTO staff and their level of experience.

Relevant practices include:
- Activities to create an institutional culture that supports knowledge transfer;
- The establishment of institutional strategies for knowledge transfer and commercialization, such as rules for transparency in contract negotiations;
- Incentives for staff to disclose inventions and support knowledge transfer by working with potential licensees;
- Complementary factors and policies that encourage academic start-ups, such as allowing faculty to create and own a share in a start-up or to take a leave of absence, providing additional financing and support, and framework conditions such as incubators and science parks.

The required institutional, financial and human resources represent a sizeable investment by universities and PROs. However, license income, particularly for universities, is highly skewed, with over 80% of license income going to 10% of universities. As a result many KTOs are unable to cover their costs and total license income, as a share of total research expenditures by universities, reaches a maximum of 4% in the United States and is approximately 1% in Europe. As a result, it unrealistic to expect license income to substantially replace other university income or funding sources.

[8] See Belenzon and Schankerman (2009), Barjak et al (2015).

The evidence stresses the importance of a *well-defined university IP policy*. Universities with internal rules regulating the participation of researchers in the transfer of technology perform better than universities without such rules.[9]

Policies to limit possible disadvantages of the IP licensing model

Universities, PROs, funding agencies, donors and governments have essentially two levers for preventing or limiting the potentially negative impacts of IP-based knowledge transfer.

First, the patenting and the licensing of specific types of inventions can be restricted. For instance, guidelines can demand that patents should be sought, and exclusive licenses attributed, only where they are a necessary condition for their commercialization. University policies and government bodies can also declare certain areas off-limits to university patenting: basic research, research tools, or technologies critical to public health in low-income countries.

Second, where inventions are patented, the type of and access to downstream licenses can be influenced by legislation or institutional policies. For instance, licensees of government-funded technologies can be required to disclose follow-on investment and the actual use of the patent, for instance avoiding that these patents are used to block follow-on inventions by incumbents or patent aggregators. Certain requirements can be instituted to ensure that products derived from these inventions are sold to consumers or poorer countries on reasonable terms.[10] Field-of-use restrictions can also be implemented to ensure that the IP is made available for future research, including to other firms. Governments can also reserve the right to practice the invention or override exclusive licensing rights (‘’march-in rights’’).

Moreover, universities and PROs are trying a number of interesting additional approaches such as Open IP Policies. These include patenting and licensing strategies (e.g. granting firms non-exclusive rather than exclusive licenses, making licenses free or cheaper if used for humanitarian or not-for-profit purposes, or for small firms or start-ups in selected technologies), and also providing easier access to research tools and to copyrighted works such as teaching materials, an often neglected IP issue in this debate.

3. Conceptual framework for the costs and benefits of the IP licensing model

Conceptually, the question is how the IP licensing model can be used by universities and PROs to drive knowledge transfer and business innovation while, at the same time, preserving the science system[11] and other effective forms of knowledge transfer. This depends, in part on the revealed advantages and disadvantages of existing and potential policy approaches and their interaction with similar knowledge transfer channels and policies. As evidenced in the previous section, effective outcomes also depend on the exact nature and details of IP policy implementation at the national, regional and often institutional level.

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[9] See Debackere and Veugelers (2005).
[10] See OECD (2003) and So *et al.* (2008).
[11] See Foray and Lissoni (2010).

The potential costs and benefits of the IP licensing model, as discussed in the literature, are summarized in Tables 1 and 2, while Table 3 adds additional notes of relevance to middle-income countries.[12] Table 1 distinguishes between possible benefits and costs for the two respective main agents – firms and public research institutions – while Table 2 summarizes the broader systemic impacts of IP licensing on science, the economy and society.

Table 1. Impacts of IP-based technology transfer policies on universities/PROs and firms

	POTENTIAL BENEFITS	POTENTIAL COSTS (OR INVESTMENTS)
UNIVERSITIES AND PROs	**1) Increased IP ownership facilitating entrepreneurship and vertical specialization** • Reinforcing other policies aimed at academic entrepreneurship (e.g., enhancing access to finance) • Licensing and other revenues (e.g., consulting) can be invested in research **2) Cross-fertilization between faculty and industry** • Intangible benefits to university reputation and the quality of research • Helping to identify research projects with a dual scientific and commercial purpose **3) Increased student intake and ability to place students in firms**	**1) Diversion of time away from academic research** • Distorting incentives for scientists and potentially also for the nature of public-oriented institutions • Reorganizing university processes and culture with a view to commercialization **2) IP-related establishment and maintenance costs** • Establishing and maintaining a TTO and related IP management, including investment in expertise and human resources • Spending time on IP filings and technology transfer (even if contracted out to a TTO) • Additional financial and reputational costs associated with defense of IP rights
FIRMS	**1) Facilitates university-business linkages** • Enabling firms to have access to top scientists and to collaborate with the scientific community in developing innovation within a clear contractual setting **2) Enables the creation of a market for ideas and contracting with universities** • Framework diminishes transaction costs and increases legal certainty, facilitating investment by private sector • Securing an exclusive license increases incentives for further investment • Ability to specialize is competitive advantage (vertical specialization) • Transparency through published databases on licensing and management practices • Improved content of patent databases **3) Commercialization of new products generating profits and growth**	**1) Barriers to access of university inventions** • Precludes free access to university inventions - including the more basic research fields and research tools, except where research is the result of a sponsored contract • Lack of access if another firm has secured an exclusive license **2) IP-based transaction costs and tensions in industry-university relationships** • University scientists lack an understanding of development costs and market needs (cognitive dissonance) leading to higher probability of bargaining breakdown • IP negotiations can interfere with establishment of joint R&D and university-industry relations, where universities act as revenue maximizer with strong stance on IP

[12] See WIPO (2011) and Zuñiga (2011).

Table 2. Systemic impacts of IP-based technology transfer policies

<table>
<tr><th></th><th>POTENTIAL BENEFITS</th><th>POTENTIAL COSTS</th></tr>
<tr><td>BROADER IMPACTS ON SCIENCE</td><td>1) Increased impact of more focused research with potential for application

2) Improved innovation system linkages
• Efficient division of labor in the generation and commercialization of new inventions
• Private sector contribution to funding basic and applied research

3) Increase in the quality of research and education</td><td>1) Reorientation of the direction of research
• Overemphasis on applied, short-term, more lucrative research
• Less diversity in scientific disciplines as focus on patentable outcomes increases
• Other university missions are neglected, such as teaching and training
2) Negative impacts on open science
• Crowds out/displaces the use of other knowledge transfer channels to industry
• Publication delays, increased secrecy, less sharing, including the withholding of data
• Decrease in international scientific exchanges
3) The promise of university income can reduce government commitment to funding</td></tr>
<tr><td>INNOVATION AND GROWTH</td><td>1) Commercialization of inventions with economic and social impacts
• Increase in consumer welfare and business productivity via access to innovative products and processes
2) (Localized) positive impacts on R&D, technology spillovers, entrepreneurship, employment and growth

3) Higher competitive position of country in global market</td><td>1) Long-run negative effect of diverting attention away from academic knowledge production
2) Long-run negative effects of IP on open science and follow-on innovation
• Patenting of broad upstream inventions, platform technologies and research tools increases the cost of follow-on research and innovation
• Reduction in the diversity of research
3) Focus on IP might inhibit rather than promote commercialization of inventions</td></tr>
</table>

Table 3: Impacts on low- and middle-income countries

<table>
<tr><th>POTENTIAL BENEFITS</th><th>POTENTIAL COSTS</th></tr>
<tr><td>1) All the same benefits mentioned above (see Tables 1 and 2)
This depends, however, on the capacity of businesses to absorb and further develop university inventions – either by domestic firms or by locally present multinational firms - and whether or not these inventions are relevant to the needs of low- and middle-income countries.
2) Ability to contribute to local or global markets for university inventions
This depends on the capacity to generate university inventions and to file patents.
University inventions might also attract the presence of multinational companies and their associated complementary R&D.
The strengthened science-industry links can help reorient research towards local needs.
3) Improved visibility of public research inventions
Local firms may find it easier to identify relevant inventions and academics through patent searches than through searches of academic literature</td><td>1) All the same above-mentioned costs (see Tables 2 and 3), some of which are amplified given the greater resource constraints of less developed economies
• Reduced or no access to critical technologies owned by universities in high-income countries
• Overemphasis on applied, lucrative projects may lead to less useful inventions from the point of view of low- and middle-income countries.
• The decrease in international scientific exchanges and a reduced eagerness of institutions in high-income countries to collaborate as a result of more complex IP ownership issues and secrecy.
• High cost of obtaining international patent protection for university inventions and the resulting opportunity costs.</td></tr>
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Advantages

Due to data availability (discussed below), we know considerably more about the IP licensing model than any other form of knowledge transfer, at least for the United States and secondarily for Europe. Patents are the classic form of IP, but IP licensing agreements between the public research sector and businesses are also made for plant varieties (plant breeders rights), biological tissue, know-how (protected under secrecy), industrial designs and copyright (relevant to software outside of the United States).[13]

Studies show that the IP licensing model has supported the emergence of new industries, such as the scientific instruments industry, semiconductors, computer software and the nano- and biotechnology industries.[14] Several major corporations originated from academic start-ups facilitated by KTOs.[15] US university start-ups also seem disproportionately more likely to develop into viable businesses and to create more jobs.[16] For instance, the US AUTM collects case studies and examples of university IP contributions over the last 25 years, with over 4,600 start-ups still operating as of the end of 2014, in particular in the health care sector.[17] The literature also shows that academic start-ups are more likely to commercialize new technologies that are radical, early stage and of a general-purpose nature.[18] Again, attributing these positive impacts exclusively to the IP licensing model is difficult in the absence of research on the role of other knowledge transfer channels.

Research on the IP licensing model has identified many secondary benefits other than its primary objective of transferring a specific set of knowledge to one or more businesses. These other benefits primarily depend on the ability of a patent to signal the presence of expertise within the university via the information contained in a patent, which can lead to mutually beneficial collaborative and contract research agreements, coop placements for graduate students, funded PhD scholarships, and improvements in research quality. The general effect is the “cross-fertilization” of ideas, problems and knowledge between faculty and industry that can facilitate joint problem solving and open up new avenues for research.[19] While this has been an ongoing trend in high-income economies over the last few decades, it has enormous potential benefits for low- and middle-income economies, particularly in building up the research capabilities of universities.

Many of the secondary benefits are not one-way exchanges from universities to firms, but benefit both parties. Industrial research complements and also guides more basic research. It is also a means of “equipping” university scientists with costly new and powerful instruments.

[13] Trademarks constitute another form of IP, but are rarely licensed by universities or PROs.
[14] See Rosenberg and Nelson (1994) and Zucker *et al.* (1998).
[15] Several major corporations began as TTO start-ups, including Genentech in biotechnology, Cirrus Logic in semiconductors, and Lycos in Internet search engines. See Di Gregorio and Shane (2003).
[16] See Di Gregorio and Shane (2003) and Shane (2004).
[17] See AUTM (2010).
[18] In contrast, licensing to established firms is used to commercialize new technologies that are more incremental, codified, late stage and specific in purpose. They also tend to involve minor technical advances, provide moderate customer value and have weaker IP protection.
[19] See Azoulay *et al.* (2006) and Owen-Smith and Powell (2003).

The signaling function can also be met through publication in scientific and technical journals, but the focus of patents on inventions with commercial possibilities could have an advantage over publications, where commercial ideas could be more time consuming (and therefore costly) for businesses to identify. Furthermore, the existence of university patents signals the willingness of the university to license knowledge on an exclusive basis, including know-how protected by secrecy.

Disadvantages

University research has been associated with the norms of rapid disclosure of research results and an environment of knowledge sharing, co-authorship and joint projects that contribute to cumulative learning. One concern is that the patenting of university inventions might have negative effects on these norms, slow the diffusion of university inventions, including research tools; and stifle innovation.[20] The exclusive licensing of patents to single firms might, in particular, limit the diffusion of knowledge generated with public funds, reducing the diversity and number of follow-on innovations.

Moreover, a strong stance on IP by universities and PROs might negatively impact other knowledge transfer channels that could be equally or more effective in supporting knowledge transfer under specific conditions. These include informal knowledge exchanges between businesses and academics as well as more formal R&D collaboration – due to the complexity of negotiating IP rights.

Surveys of scientists have documented increased secrecy and delays in publication; in addition, a refocusing of research activity can accompany the involvement of particular researchers in patenting and commercialization activity.[21] Examples have been noted of companies restricting the findings of university researchers or researchers denying others access to their data.[22] Despite these examples, no broad evidence exists that could unambiguously demonstrate alarming impacts that cannot be managed with good university codes of practice. [23]

The risk of industry exerting an undue influence on academic research is constrained by the small share of university R&D that it funds.[24] In the US, for example, industry finances about 5 to 6 percent of all basic and applied academic R&D, respectively, with a focus on basic R&D (see Figure 4.11), although its share (and likely influence) is much higher in health-related R&D.

[20] See Eisenberg (1989); Heller and Eisenberg (1998); and Kenney and Patton (2009). The latter authors note that the institutional arrangements within which TTOs are embedded have encouraged some of them to become revenue maximizers rather than facilitators of technology dissemination for the good of the entire society.
[21] See, for an overview of this literature, Azoulay *et al.* (2009).
[22] See, for instance, Campbell *et al.* (2002); Campbell *et al.* (2000); and the related literature.
[23] See, for good overviews Grimaldi *et al.* (2011); Fabrizio and Di Minin (2008); and Czarnitzki *et al*. (2009).
[24] Official statistics show a modest but increasing share of industry-funded R&D carried out in academia. In OECD countries this has increased from an average of 2.9 percent in 1981 to about 6.6 percent in 2007. In Argentina, China and the Russian Federation, firms also fund a stable or increasing percentage of academic R&D.

Another potential disadvantage is due to the unintended effects of the adoption by universities of a proactive patenting strategy. The fact that universities insist on their own IP terms prior to working with industry has been framed as a barrier to collaboration, given the long delays and potential for friction where universities act to maximize profits.[25] Some frustration stems from the fact that universities may deploy a "one-size-fits-all" approach to patenting research results, notwithstanding the evidence that patents and exclusive licensing play different roles in the development of complex versus discrete technologies.[26]

Few studies have assessed this potential downside effect. Instead, studies show that often – and despite potential friction - university IP, collaboration and research productivity go hand in hand. In other words, those universities that collaborate more with industry also tend to be the ones with the most patents – again, no causality is implied.

The patenting of university inventions in high-income countries could restrict access to research tools, databases and technologies by businesses in low and middle-income countries.[27] In particular, stricter IP practices may hinder access to technologies that are particularly critical for less developed economies, for example in agriculture and health and for essential medicines.[28]

Another concern is that opportunities for scientific networking between scientists in high-income and less developed countries might be reduced.[29] Examples have been cited of cooperation agreements between institutions of more and less developed countries being abolished due to across-the-board patenting strategies.

4. Assessing Knowledge Transfer Capabilities and Policies

The implication of the previous sections is that policies to encourage and support knowledge transfer must be designed to support multiple channels for knowledge flow and take into consideration the advantages and disadvantages of each channel and the suitability of different types of knowledge to specific channels. The role of KTOs has also been changing in Europe to take these issues into account, with a greater recognition of the need for KTOs to support informal channels (for instance by arranging 'meet and greet' events between academics and business), in addition to their traditional role in supporting the IP licensing model.

Universities and PROs can also create a supportive environment for knowledge transfer through secondary activities such as educational programs to teach entrepreneurship to students and faculty and by creating innovation incubators and science parks.[30] Incubators and science parks can attract businesses to conduct some of their activities close to the university and encourages contacts with researchers and entrepreneurial students and staff.

Metrics for IP-based knowledge transfer

[25] See Alexy *et al.* (2009) and Wadhwa (2011). Specific firms have argued that it has distanced universities from firms in the US and has been a reason for US firms to collaborate more with firms abroad. See Litan *et al.* (2008).
[26] See So *et al.* (2008).
[27] See Boettiger and Benett (2006); So *et al.* (2008); Montobio (2009); and Engel (2008).
[28] See Boettiger. (2006).
[29] See Clemente (2006).
[30] See Rothaermel *et al.* (2007).

A serious drawback to assessing what works best under different conditions is the lack of good metrics for informal knowledge flows. Obtaining relevant data requires either surveying businesses or academics, which is a costly process. There have been no attempts to obtain this information on a regular basis, with the last large-scale survey on the channels used by businesses in the United States and Europe to acquire university knowledge conducted in 1994 and 1993 respectively. Consequently, at this time a framework for identifying the role of informal knowledge transfer channels must rely on case studies to identify forms that might be widely-used in specific countries.[31]

Conversely, metrics on formal or IP-based knowledge transfer channels can be obtained at a considerably lower cost by surveying KTOs. KTOs have been established at most research-intensive universities in high-income countries, such as the member states of the European Union, the United States, Canada, Australia and New Zealand. Seven comparative metrics have been collected in these countries (although with the exception of the US, the UK and Denmark, not on an annual basis): the number of 1) invention disclosures, 2) patent applications, 3) patent grants, 4) research agreements, 5) license agreements, 6) start-up establishments and 7) total license revenue earned. Many of these metrics can be standardized for both internal and international comparisons, for instance by calculating the rate of patent grants per 1,000 academic staff or per 1,000,000 USD in purchasing power parities for research expenditures.[32] There is less information on the use and prevalence of these metrics in middle-income countries.

An important point is that these seven metrics and other metrics vary in their ability to measure commercialization. Invention disclosures are at the farthest point from commercialization and primarily refer to an unknown potential for commercialization (many on closer inspection may have no commercialization potential at all, with the KTO declining to make a patent application). The best commercialization measures out of the seven widely-used metrics are the number of start-ups established and license revenue, although license revenue can be earned without any down-stream commercialization, as with the Cohen-Boyer patents, which covered a widely-used research technique used in biotechnology. Data on actual commercialization requires the ability to limit license revenues to royalties from sales.

Conceptually, there are three categories of metrics for IP-based knowledge transfer (the list of examples given below are not complete):

1. Knowledge with potential commercial applications

    1. Invention disclosures
    2. Patent applications
    3. Patent grants
    4. Other forms of IP (plant breeders rights, industrial designs, etc)

[31] The successor to the KT metrics project, funded by the European Commission, has implemented a survey of academics, but results are not yet available.

[32] Arundel and Bordoy (2010) explore the possibilities and difficulties of developing internationally comparable output indicators for the commercialization of public science.

2. Early stage commercialization

1. Number of start-ups established using university/PRO IP
2. Number of license agreements
3. Earned license revenue
4. Number of research agreements

3. Economic impacts

1. Earned revenue from royalties on product sales
2. Number of commercially viable start-ups
3. Sales from products derived from university/PRO IP
4. Employment creation based on university/PRO IP

The first and second categories include all types of metrics that are currently collected on a comprehensive basis, for instance through nationally representative surveys of universities.

The third category is of greatest interest to policy, but there are substantial challenges for collecting these metrics, with most evidence to date based on case studies and examples of best practice. The easiest metric to collect is the first one on earned revenues from royalties, as it establishes that the IP has been commercialized, followed by the second metric. However, neither of these two metrics provides a measure of downstream economic impacts, which require the third or fourth metrics (or variations of these). Furthermore, although European KTOs have begun to track outcomes for start-ups (relevant to the second metric in this category), there is not yet agreement on the type of information that should be collected over time (Arundel et al, 2013).

Metrics for policies and practices to support IP-based knowledge transfer
In order to identify the types of policies that best support the commercialization of publicly-funded inventions, one also needs data on relevant policies and practices. These include both policies at the national level and policies and practices that are implemented at the level of each university or PRO. There are two main categories for policy metrics for supporting IP based knowledge transfer:

1. Metrics on policies implemented at the national or regional level

1. Ownership rules for IP produced by universities or PROs, including for when IP is produced through university-business research agreements or under contract research.
2. Regulations or guidelines on the licensing of IP (preferred licensees, exclusive and non-exclusive licensing, etc)
3. Financial support programs (funding for KTOs, venture capital, seed funding, etc)

2. Policies and practices implemented at the institutional level

1. Ownership rules (these may differ between institutions, for instance if there are no national regulations on ownership)
2. Regulations or guidelines on the licensing of IP (preferred licensees, exclusive and non-exclusive licensing, etc)
3. Incentives for inventors to disclose inventions or support IP commercialization
4. Rules that allow academics to take leave to work at a firm or start-up
5. Rules over delaying publication to permit IP licensing
6. Transparency practices, such as published model contracts and rules for negotiations
7. Supporting activities to advertise IP and search for potential business licensees

Furthermore, metrics for other drivers of successful commercialization of academic research – whether via licensing or an academic spin-off - and the different vectors of university-industry knowledge transfer need to considered. Some of these drivers include the characteristics of the KTO itself, such as the number of employees or its degree of experience (proxied by the age of the KTO or the qualifications of its professional staff).

References

Alexy, O., Criscuolo, P. & Salter, A. (2009). Does IP Strategy Have to Cripple Open Innovation? *MIT Sloan Management Review, October 1, 2009*.

Arundel, A. & Bordoy, C. (2010). Developing Internationally Comparable Indicators for the Commercialization of Publicly-funded Research. *UNU-MERIT Working Paper Series, 075*.

Arundel A, Barjak F, Es-Sakdi N, Barjak F, Perrett P, Samuel O, Lilischkis S, (2013) *Knowledge Transfer Study 2010-2012*, 385 pp. Report for DG Research and Innovation, Brussels, June. ISBN 978-92-79-32388-1.

AUTM (2010). The Better World Report - A Positive Impact of Academic Innovations on Quality of Life. Deerfield: The Association of University Technology Managers.

Azoulay, P., Ding, W. & Stuart, T. (2009). The Impact of Academic Patenting on the Rate, Quality and Direction of (Public) Research Output. *The Journal of Industrial Economics, 57*(4), 637-676.

Barjak F, Es-Sadki N, Arundel A. The effectiveness of policies for formal knowledge transfer from European universities and public research institutes to firms, *Research Evaluation*, 24:4-18, 2015.

Belenzon, S. & Schankerman, M. (2009). University Knowledge Transfer: Private Ownership, Incentives, and Local Development Objectives. *Journal of Law and Economics, 52*(1), 111-144.

Boettiger S., B.A.B. (2006). The Bayh-Dole Act: Implications for Developing Countries. *IDEA: The Intellectual Property Law Review, 46*(2), 259-279.

Campbell, E.G., Clarridge, B.R., Gokhale, M., Birenbaum, L., Hilgartner, S., Holtzman, N.A. & Blumenthal, D. (2002). Data Withholding in Academic Genetics: Evidence from a National Survey. *Journal of the American Medical Association, 287*(4), 473-480.

Campbell, E.G., Weissman, J.S., Causino, N. & Blumenthal, D. (2000). Data Withholding in Academic Medicine: Characteristics of Faculty Denied Access to Research Rsults and Biomaterials. *Research Policy, 29*(2), 303-312.
Clemente, F.-P. (2006). The Impact of Stronger Intellectual Property Rights on Science and Technology in Developing Countries. *Research Policy, 35*(6), 808-824.
Czarnitzki, D., Glänzel, W. & Hussinger, K. (2009). Heterogeneity of Patenting Activity and Its Implications for Scientific Research. *Research Policy, 38*(1), 26-34.
Debackere, K. & Veugelers, R. (2005). The Role of Academic Technology Transfer Organizations in Improving Industry Science Links. *Research Policy, 34*(3), 321-342.
Di Gregorio, D. & Shane, S. (2003). Why Do Some Universities Generate More Start-ups than Others? *Research Policy, 32*(2), 209-227.
Eisenberg, R. (1989). Patents and the Progress of Science: Exclusive Rights and Experimental Use. *University of Chicago Law Review, 56*, 1017-1055.
Engel, N. (2008). University Patenting and its Effects: An Assessment for Developing Countries. In C. S. Krishna (Ed.). *Technology Transfer: Intellectual Property Rights*. Hyderabad: Amicus Books/The Icfai University Press, 127-142.
Fabrizio, K.R. & Di Minin, A. (2008). Commercializing the Laboratory: Faculty Patenting and the Open Science Environment. *Research Policy, 37*(5), 914-931.
Foray, D. & Lissoni, F. (2010). University Research and Public-Private Interaction. In B.H. Hall & N.Rosenberg (Eds.), *Handbook of the Economics of Innovation* (Vol. 1). Amsterdam: North Holland, pp. 275-314.
Grimaldi, R., Kenney, M., Siegel, D.S. & Wright, M. (2011). 30 Years after Bayh-Dole: Reassessing Academic Entrepreneurship. *Research Policy, 40*(8), 1045-1057.
Heller, M. & Eisenberg, R. (1998). Can Patents Deter Innovation? The Anticommons in Biomedical Research. *Science, 280*, 698-701.
Litan, R.E., Mitchell, L. & Reedy, E.J. (2008). Commercializing University Innovations: Alternative Approaches. In A.B. Jaffe, J. Lerner & S. Stern (Eds.), *Innovation Policy and the Economy* (Vol. 8). Cambridge, MA: MIT Press, pp. 31-57.
Luan, C., Zhou, C. & Liu, A. (2010). Patent Strategy in Chinese Universities: A Comparative Perspective. *Scientometrics, 84*(1), 53-63.
Montobbio, F. (2009). Intellectual Property Rights and Knowledge Transfer from Public Research to Industry in the US and Europe: Which Lessons for Innovation Systems in Developing Countries? *The Economics of Intellectual Property: Suggestions for Further Research in Developing Countries and Countries with Economies in Transition*. Geneva: World Intellectual Property Organization.
OECD (2003). *Turning Science into Business - Patenting and Licensing at Public Research Organisations.* Paris: Organisation for Economic Co-operation and Development.
Owen-Smith, J. & Powell, W.W. (2003). The Expanding Role of University Patenting in the Life Sciences: Assessing the Importance of Experience and Connectivity. *Research Policy, 32*(9), 1695-1711.
Rosenberg, N. & Nelson, R.R. (1994). American Universities and Technical Advance in Industry. *Research Policy, 23*(3), 323-348.

Rothaermel, F.T., Agung, S.D. & Jiang, L. (2007). University Entrepreneurship: A Taxonomy of the Literature. *Industrial and Corporate Change, 16*(4), 691-791.
Shane, S. (2004). *Academic Entrepreneurship*. Cheltenham: Edward Elgar.
So, A.D., Sampat, B.N., Rai, A.K., Cook-Deegan, R., Reichman, J.H., Weissman, R. *et al.* (2008). Is Bayh-Dole Good for Developing Countries? Lessons from the US Experience. *PLoS Biol, 6*(10), e262.
Wadhwa, V. (2011). Innovation's Golden Opportunity*. Washington Post*. Retrieved from *http://wadhwa.com/2011/06/12/washington-post-innovation%E2%80%99s-golden-opportunity/*
WIPO. (2011). “Harnessing Public Research for Innovation – The Role of Intellectual Property”, Chapter 4 in World Intellectual Property Report 2011: The Changing Face of Innovation. Author: Sacha Wunsch-Vincent, Geneva: World Intellectual Property Organization (WIPO). http://www.wipo.int/edocs/pubdocs/en/wipo_pub_944_2011-chapter4.pdf
Zucker, L.G., Darby, M.R. & Brewer, M.B. (1998). Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises. *The American Economic Review, 88*(1), 290-306
Zuñiga, P. (2011), The state of patenting at research institutions in developing countries: Policy approaches and practices, WIPO Economics Research Working Papers No. 4, Geneva: WIPO, http://www.wipo.int/edocs/pubdocs/en/wipo_pub_econstat_wp_4.pdf.