CHAPTER 4
HARNESSING PUBLIC RESEARCH FOR INNOVATION – THE ROLE OF INTELLECTUAL PROPERTY

Universities and public research organizations (PROs) play a key role in innovation through their contribution to the production and diffusion of knowledge.[1]

In the last decades, various national strategies have aimed to improve the linkages between public research and industry. As innovation becomes more collaborative, the objective will be to find the most adequate frameworks for spurring the commercialization of publicly-funded inventions. Universities are therefore fostering entrepreneurial activity along many dimensions, including by creating incubators, science parks and university spin-offs.[2]

In the above context, patenting and licensing inventions based on public research are used as instruments for accelerating knowledge transfer, fueling greater cross-fertilization between faculty and industry which leads to entrepreneurship, innovation and growth. While this has been an ongoing trend in high-income economies over the last decades, it is increasingly also a matter of priority in low- and middle-income economies. This has raised numerous questions regarding the resulting economic and other impacts, including those on the broader science system.

This chapter reviews the developments and outcomes of these approaches for countries at different stages of development.

The first section of this chapter assesses the role of universities and PROs in national innovation systems. The second section describes the ongoing policy initiatives that promote university and PRO patenting and licensing, and presents new data. The third section evaluates the impacts of these policies based on the findings of the growing empirical literature, while the fourth section is concerned with implications for middle- and low-income countries. Finally, the fourth section presents new practices that act as safeguards against the potential downside effects of commercializing publicly-funded research. The analysis is supplemented by a background report to this chapter (Zuñiga, 2011).

The concluding remarks summarize some of the key messages emanating from the economic literature and point to areas where more research could usefully guide policymakers.

1 The text mostly covers universities and PROs. At times, the term "public research institutions" 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.

2 See Rothaermel *et al.* (2007).

4.1

The evolving role of universities and PROs in national innovation systems

Universities and PROs play a key role in national innovation systems and in science more broadly. This has to do with the magnitude and direction of public research and development (R&D) (see Subsection 4.1.1) and the impacts of these public research institutions on the broader innovation system at different levels: first by providing human capital and training, advancing knowledge through public science, and lastly through technology transfer activities (see Subsection 4.1.2).

4.1.1

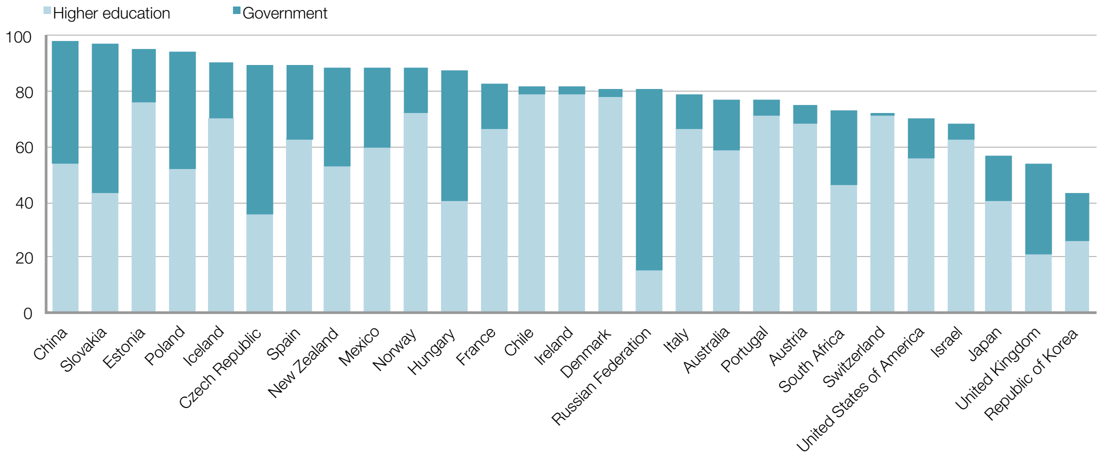
Public R&D is key, in particular for basic research

The R&D conducted by universities and PROs accounts for a substantial share of total R&D.

In high-income economies, the public sector is responsible for anywhere between 20 and 45 percent of annual total R&D expenditure (see Annex Figure 4.1). Importantly, with some exceptions governments usually provide the majority of the funds for basic research.[3] On average, in 2009 the public sector performed more than three-quarters of all basic research in high-income economies (see Figure 4.1).[4] This contribution to basic research is becoming more vital as firms focus mostly on product development and as multinational companies in high-income countries scale back their basic research in a number of R&D-intensive sectors.[5]

Figure 4.1: Basic research is mainly conducted by the public sector

Basic research performed in the public sector for 2009 or latest available year, as a percentage of national basic research



Note: The above graph provides data from the most recent available years, mostly between 2007 and 2009 for each country, except Mexico for which the year provided is 2003. As noted in footnote 1, some of the distinction between higher education institutions – universities and government as well as PROs – is simply definitional and depends on what is defined as a university or a PRO in a given country.

Source: Organisation for Economic Co-operation and Development (OECD), Research and Development Database, May 2011.

3 Basic research means experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.

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 See OECD (2008b).

PROs – rather than universities – are often the main R&D actors in low- and middle-income economies, where – in many cases – industry often contributes little to scientific research (see Chapter 1 and Annex Figure 4.1). On average, government funding is responsible for about 53 percent of total R&D in the middle-income countries for which data are available.[6] As the level of a country's income decreases, governmental funding approaches 100 percent, in particular for R&D in the agricultural and health sectors. For instance, the public sector funded 100 percent of R&D in Burkina Faso in the last year for which data are available. R&D is also essentially conducted by PROs. For example, In Argentina, Bolivia, Brazil, India, Peru and Romania the share of public-sector R&D often exceeds 70 percent of total R&D.[7]

In low- and middle-income countries for which data are available, public research is also responsible for the majority of basic R&D, e.g., close to 100 percent in China, close to 90 percent in Mexico, about 80 percent in Chile and the Russian Federation, and about 75 percent in South Africa.

4.1.2

Public R&D stimulates private R&D and innovation

Beyond the mere contribution to total R&D, the economic literature stresses that universities and PROs – and science more generally – are a fundamental source of knowledge for the business sector (see Box 4.1).[8]

Firms and other innovators depend on the contributions of public research and of future scientists to produce innovation of commercial significance.[9] Science serves as a map for firms, facilitating the identification of promising venues for innovation, avoiding duplication of efforts by companies. Close interaction with public research enables firms to monitor scientific advances likely to transform their technologies and markets. It also facilitates joint problem solving and opens up new avenues for research. Given the increasingly science-based nature of technological advances, this interaction with science is more and more key to innovation.[10]

Box 4.1: The economic impact of publicly-funded research

The economic rationale for publicly-funded research relates largely to the concept of appropriability discussed in Chapter 2. Economists have traditionally seen knowledge produced by universities and PROs as a public good. First, the economic value attached to certain kinds of basic and other research cannot be fully appropriated by the actor undertaking the research. Second, the value of such knowledge is often difficult or impossible to judge ex ante. As a result, firms alone would tend to underinvest in the funding of research, in particular in fields that show little prospect of near-term profitability.

To avoid this underinvestment in science and research, governments fund research. Scientists are thus enabled to pursue blue-sky research without the pressure of immediate business considerations.[11] The reward system is based on the scientist's publication and dissemination record.[12]

6 See UNESCO (2010).
7 Exceptions are Malaysia, China, the Philippines and Thailand where, for both R&D funding and performance, the business sector has the largest share but, nonetheless, PROs play a key role in contributing to industry R&D and ensuing innovation.
8 See Caballero and Jaffe (1993).
9 See Nelson (2004).
10 See Section 3.4 on technology-science linkages; OECD (2011) based on patents citing non-patent literature (forward and backward citations). Patents that rely on scientific knowledge are on the increase in high-growth industries such as biotechnology, pharmaceuticals and information and communication technologies (ICT).
11 See Stephan (2010).
12 See Jaffe (1989).

Economic studies have examined the impact of academic research on business innovation.[13] While imperfect, aggregate studies have found that academic research, and basic research in particular, has a positive effect on industrial innovation and industry productivity.[14] Importantly, public R&D does not directly contribute to economic growth but has an indirect effect via the stimulation of increased private R&D. In other words, "crowding in" of private R&D takes place as public R&D raises the returns on private R&D.[15]

Yet, the effect of public R&D is mostly found to be smaller in size than the impact of private R&D. The link to an immediate commercial application is not direct. Moreover, detailed econometric studies at the firm and industry level provide less conclusive results as to the positive impact of public R&D.

This failure to show a strong impact can convincingly be blamed on the difficulty in constructing such empirical studies. Given the many channels of knowledge transfer, assigning a figure to all associated impacts is challenging. Many transactions rarely leave a visible trace that can be readily identified and measured.[16] The contribution of public R&D can take also a long time to materialize. Finally, the non-economic impact of research in areas such as health, and others, is even harder to identify. Yet it is of an equally, if not more important, nature.

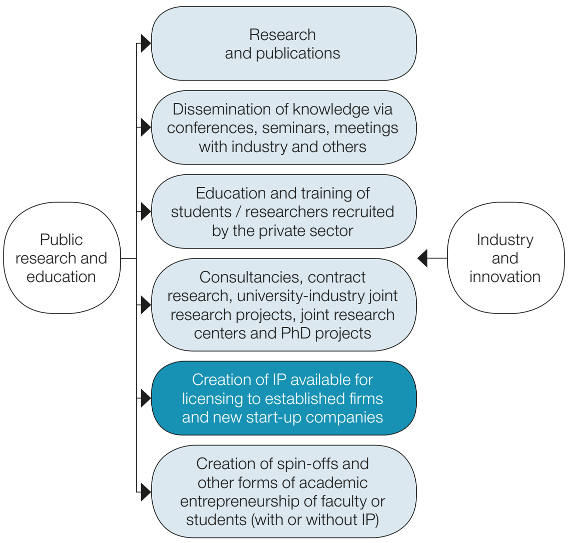
Although this chapter focuses on the role of intellectual property (IP), public-private knowledge transfer occurs through a large number of formal and informal channels, and IP issues are only one part of the bigger landscape. Figure 4.2 sets out the following informal and formal channels of exchange:[17]

- **Informal channels** include the transfer of knowledge through publications, conferences and informal exchanges between scientists.

- **Formal channels** include hiring students and researchers from universities and PROs, sharing equipment and instrumentation, contracting technology services, research collaboration, creating university spin-offs or joint firms, and newer IP-related transmission channels such as licensing inventions from universities.[18]

It is through informal as opposed to formal links that knowledge most frequently diffuses to firms. Formal and "commercial" channels of knowledge transfer are frequently ranked lower in importance in firm surveys for high-, middle- and low-income countries.[19] Importantly, policies or research that account for only one type of linkage will thus provide only a partial understanding of the patterns of interaction and their inter-reliant nature.

Figure 4.2: The multiple vectors of knowledge transfer from universities and PROs to industry



13 For example, Adams (1990) has found that basic research has a significant effect on increasing industry productivity, although the effect may be delayed for 20 years. Similarly, Manfield's survey of R&D executives from 76 randomly selected firms estimated that 10 percent of industrial innovation was dependent on the academic research conducted within the 15 years prior. See also Mansfield (1998).
14 See Griliches (1980), Adams (1990) and Luintel and Khan (2011).
15 For an overview of the literature, see David and Hall (2006). In turn, some public R&D may crowd out private R&D if it is not focused on basic (pre-commercial) R&D.
16 See Vincett (2010) and OECD (2008a).
17 See Bishop *et al.* (2011) and Merrill and Mazza (2010).
18 See Foray and Lissoni (2010).
19 See Zuñiga (2011).

The payoffs of academic research are maximized when the private sector uses and builds on these multiple channels of transfer.[20] These are not one-way exchanges from universities to firms. Industrial research complements and also guides more basic research. It is also a means of "equipping" university scientists with new and powerful instruments.

For knowledge transfer to work, firms need to be able to assimilate and exploit public research. Often this is attained by firms actively engaged in upstream research activity and actively participating in science.[21] Promoting outward knowledge transfer from universities and PROs where this capacity does not exist will be ineffective.

Fostering this two-way exchange, which builds on the mutual capacities of the public and private research sectors, is a challenge for high-income countries but particularly so for less developed economies with fewer links among PROs, universities and the private sector (see Section 4.4).

4.1.3

Fostering the impact of publicly-funded research on innovation

Based on the above, policymakers have been keen to bolster the effectiveness with which publicly-funded research can foster commercial innovation.[22]

Since the late 1970s, many countries have changed their legislation and created support mechanisms to encourage interaction between universities and firms, including through technology transfer.[23] Placing the output of publicly-funded research in the public domain is no longer seen as sufficient to generate the full benefits of the research for innovation.[24] Also, countries have intended that budget cuts to universities should be compensated by proactive approaches to revenue generation.[25]

In high-income countries, policy approaches promoting increased commercialization of the results of public research have included reforming higher education systems; creating clusters, incubators and science parks; promoting university-industry collaboration; instituting specific laws and institutions to regulate technology transfer; and encouraging public research institutions to file for and commercialize their IP.

The transformation of research institutions into more entrepreneurial organizations is also taking place in middle- and low-income countries by increasing the quality of public research, creating new incentives and performance-linked criteria for researchers, enhancing collaboration of universities and PROs with firms, and setting up mechanisms for formal technology transfer.[26]

20 See David *et al.* (1992).
21 See Cohen and Levinthal (1989).
22 See Foray and Lissoni (2010) and Just and Huffman (2009).
23 See Van Looy *et al.* (2011).
24 See OECD (2003) and Wright *et al.* (2007).
25 See Vincent-Lancrin (2006). There is increasing evidence that countries seek to recover the full economic cost of research activity in order to allow research institutions to amortize the assets and overhead, and to invest in infrastructure at a rate adequate to maintain future capability.
26 See Zuñiga (2011).

4.2

Public research institutions' IP comes of age

4.2.1

Developing policy frameworks for technology transfer

University- and PRO-industry relationships have existed for many years, and there have long been efforts to commercialize public research, even before legal acts began to facilitate the commercialization of patents.[27]

In the last three decades, however, the legislative trend to incentivize university and PRO patenting and commercialization has clearly intensified (see Box 4.2). Almost all high-income countries have adopted specific legislative frameworks and policies.[28]

Promoting technology transfer and the development of industry-university collaboration has only been given attention much later in less developed economies.[29] Recently a number of more advanced middle- and low-income economies have followed suit.

Box 4.2: A short history of university technology transfer legislation

In the 1960s, Israel was the first country to implement IP policies for several of its universities. However, in 1980 the Bayh-Dole Act of the US was the first dedicated legal framework which institutionalized the transfer of exclusive control over many government-funded inventions to universities and businesses operating under federal contracts. The shift and clarification of ownership over these inventions lowered transaction costs as permission was no longer needed from federal funding agencies, and because this gave greater clarity to ownership rights and therefore greater security to downstream – sometimes exclusive – licensees. For instance, the Act also contains rules for invention disclosure and requires institutions to provide incentives for researchers. It also contains march-in provisions reserving the right of government to intervene under some circumstances (see Section 4.5).

Several European, Asian and other high-income countries have adopted similar legislation, in particular as of the latter half of the 1990s onwards.[30] In Europe, in many cases the challenge was to address the established situation according to which IP ownership was assigned to the faculty inventor – the so-called professor's privilege – or to firms that funded the researchers rather than to the university or PRO itself.[31] Since the end of the 1990s, most European countries have been moving away from inventor ownership of patent rights towards university or PRO ownership.[32] European policy efforts have sought to increase both IP awareness within the public research system and the rate of commercialization of academic inventions. In Asia, Japan was the first to implement similar legislation in 1998 and, in 1999, shifted patent rights to public research institutions. The Republic of Korea implemented similar policies in 2000.

A number of middle- and low-income countries have also moved in this direction, whereas in other such countries these efforts are still nascent (for more details, see Zuñiga, 2011).

27 See Mowery *et al.* (2004); and Scotchmer (2004). In the US, in particular, technology transfer organizations, such as the Research Corporation created in 1912, have sought to commercialize academic research and to channel monetary gains back into research.
28 See OECD (2003) and Guellec *et al.* (2010).
29 See Kuramoto and Torero (2009).
30 See Geuna and Rossi (2011) and Montobbio (2009).
31 See Cervantes (2009) and Foray and Lissoni (2010).
32 Professor's privilege was abolished in Germany, Austria, Denmark, Norway and Finland during the period 2000-2007, but was preserved in Sweden and Italy where, in the latter, professor's privilege was introduced in 2001.

In spite of the lack of an explicit policy framework, many of these countries have put in place general legislation regulating or facilitating IP ownership and commercialization by research institutions (see Annex, Table A.4.1).[33] There are four distinct sets of countries. In the first set, there is no explicit regulation, but rather general rules defined in the law – mostly in patent acts – or legislation regulating research institutions or government funding. A second model consists of laws in the form of national innovation laws. A third, adopted in Brazil, China, and more recently in economies such as Malaysia, Mexico, the Philippines and South Africa, builds on the model of high-income countries which confers IP ownership to universities and PROs, spurring them to commercialize. Fourth, some countries, for example Nigeria and Ghana, have no national framework but rely on guidelines for IP-based technology transfer.

Fast-growing middle-income economies, such as Brazil, China, India, the Russian Federation and South Africa, have already implemented specific legislation or are currently debating its introduction (see Annex, Table A.4.1). China was among the first to adopt a policy framework in 2002.[34] In addition, a significant number of countries in Asia – in particular Bangladesh, Indonesia, Malaysia, Pakistan the Philippines, and Thailand – and in Latin America and the Caribbean – in particular Brazil, Mexico and more recently Colombia, Costa Rica and Peru – have been considering such legislation.[35] However, only Brazil and Mexico have enacted explicit regulations regarding IP ownership and university technology transfer so far. In India, institutional policies have recently been developed at key national academic and research organizations, complementing legislative efforts which aim to implement university IP-based technology transfer rules.[36]

In Africa, most countries other than South Africa have neither a specific law on IP ownership by research institutions nor any technology transfer laws. However, several countries have started to implement policy guidelines and to support technology transfer infrastructure. Nigeria and Ghana for instance do not have specific legislation but are both in the process of establishing technology transfer offices (TTOs) in all institutions of higher education.[37] Algeria, Egypt, Morocco and Tunisia have been working on drafts for similar legislation. In 2010, South Africa implemented the Intellectual Property Rights from Publicly Financed R&D Act, which defines a number of obligations ranging from disclosure, IP management and inventor incentives, to the creation of TTOs and policies regarding entrepreneurship.

33 See Zuñiga (2011). Thailand and the Russian Federation, for instance, do not have specific legislation defining ownership and commercialization rules for research funded by the federal budget at universities and PROs. Yet existing revisions to the patent law or other policies leave universities the flexibility to create and own their own IP.

A review of existing mechanisms reveals a few important lessons. 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 (see Box 4.2) as well as how it is designed with respect to 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 (see Subsection 4.4.1 and Section 4.5).[38] 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 (see Section 4.3).

34 In 2002, the government provided universities with full rights of ownership and commercialization for inventions derived from state-funded research. The "Measures for Intellectual Property Made under Government Funding" legislation provides specific rules for IP ownership and licensing, inventor compensation and firm creation.

35 See Zuñiga (2011) and internal contributions to this report made by WIPO's Innovation and Technology Transfer Section.

36 See Basant and Chandra (2007).

37 Nigeria is in the process of establishing TTOs inall institutions of higher education and research. In terms of its policy framework; however, there is no specific law on IP creation and management at publicly-funded research institutions. Instead, regulations are set within federal research institutes and, recently, the the National Office for Technology Acquisition and Promotion (NOTAP) published "Guidelines on Development of Intellectual Property Policy for Universities and R&D Institutions". These guiding principles explain how each R&D institution can formulate and implement its IP policy to protect tangible research products in order to make them demand-driven and economically viable. The guidelines also promote the use of IP for the benefit of society, and strengthen research-industry linkages by establishing intellectual property and technology transfer offices (IPTTO).

38 These can range from legal approaches (stand-alone or as part of more comprehensive reforms) and university by-laws, to "codes of practice" or general guidelines on IP ownership and management for fostering greater transparency and consistency. See Grimaldi *et al* (2011) and OECD (2003).

Most policies and practices are in flux in both more and less developed countries as policymakers strive to improve the linkages between public R&D and innovation. The policy options being manifold and intricate, it is best not to center policy discussion on simple binary choices, i.e., whether ownership of inventions by public research institutions is a good or a bad thing.

Finally, legal changes alone have not started or contributed to sustained patenting by public research institutions. In the US, university patenting is said to also have been driven by growing technological opportunities in the biomedical and other high-tech fields, as well as a culture change favoring increased university-industry linkages.[39]

4.2.2

Measuring the increase in university and PRO patenting

In the absence of comprehensive data on formal and informal university-industry relationships, figures on patents and licenses are used by researchers and policymakers to gain insights into university knowledge transfer and research performance. The idea is to gauge the patenting output of these institutions in order to detect the evolution over time, to enable cross-country comparisons and to benchmark performance. While this has been influential in the policy debate, there are certain related caveats (see Box 4.3). An important one is the fact that patent data do say relatively little about whether these patents do actually result in innovations. In that sense, patent data stay a relatively imperfect measure of technological activity.[40]

This subsection presents novel data for university and PRO patenting under the Patent Cooperation Treaty (PCT) and less complete data at the national level (see the Methodological Annex). It is appealing to use data based on PCT filings as they are complete and comparable across countries. Identifying universities' and PROs' patents on the basis of statistics from the PCT system is therefore also more straightforward. Only a fraction of national patents – most likely the more valuable ones – are filed in addition under the PCT. Also, PCT data underestimate the activity of non-PCT members, such as Argentina and other Latin American countries. Looking only at PCT data will thus provide a partial picture of patenting by public research institutions. For that reason, an effort has been made to show estimates for national patenting as well.

39 See Mowery *et al.* (2001).

40 See Khan and Wunsch-Vincent (2011).

Box 4.3: Caveats in the use of the available data on universities' and PROs' patents

When using data on universities' and PROs' patents to compare the efficacy of university technology transfer across institutions or countries, two technical issues must be kept in mind.

First, it is difficult to appropriately identify patents filed in the name of a university or PRO. Patent documents do not contain standardized information on the affiliation of the applicant to a particular category: public, private, university, hospital, etc. One can only rely on the information contained in the applicant's name or address in developing search algorithms to identify universities' and PROs' patents.

Second, a large share of inventions originating from research performed at universities or PROs – university-invented patents – are not patented under the institution's name. Frequently, researchers patent separately either as individuals or through companies. According to some studies, in Europe, the number of university-owned patents is frequently a small fraction of university-invented patents: 4 percent in Germany and Italy, 12 percent in France, 20 percent in the Netherlands, 32 percent in the United Kingdom (UK) and 53 percent in Spain.[41] Firms in Europe own no less than 60 percent of academic patents.[42] Also, university researchers in the United States of America (US) often do not disclose valuable inventions to a TTO. The same trends are true for PROs. As a result, a sizeable share of patents derived from public research goes unmeasured.

The patents which universities and PROs file under the PCT are steadily increasing

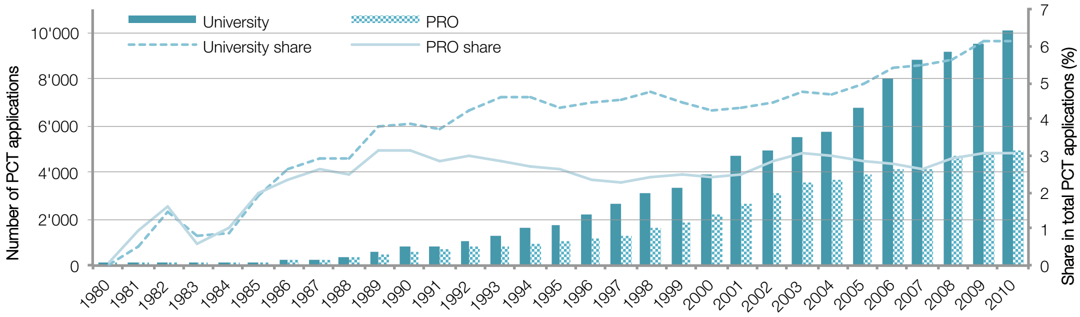
Since 1979, the number of international patent applications filed under the PCT by universities and PROs has been steadily increasing, except for a drop in 2009 linked to broader economic conditions. In fact, these university and PRO filings have grown faster than total PCT applications over the period 1980-2010. The compound annual growth rate for this period was about 13 percent for all PCT applications, 35 percent for university applications and about 29 percent for PRO applications.

Figure 4.3 shows totals worldwide for both university and PRO applications as well as their share of total applications filed. Most of the growth in applications is driven by high-income economies, where France, Germany, Japan, the UK and the US represent approximately 72 percent of all university and PRO PCT applications in the selected period. The share of universities' and PROs' patents out of total patents under the PCT has been increasing since 1983, reaching 6 percent for universities and 3 percent for PROs in 2010. This shows that, despite the increase in university applications, the PCT system is mostly used by firms, in particular in high-income countries which still make up for the most filings under the PCT.

41 See Daraio *et al.* (2011).
42 See Lissoni *et al.* (2008).

Figure 4.3: Universities' and PROs' patents are increasing under the PCT

PRO and university PCT applications worldwide, absolute numbers (left) and as a percentage of total PCT applications (right), 1980-2010



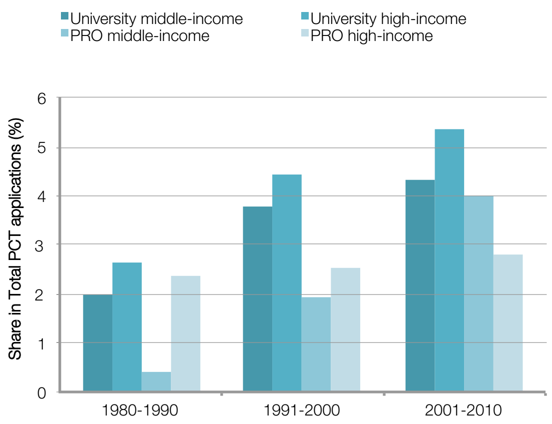
Note: As noted in footnote 1, the distinction between universities and PROs often depends on the definition in a given country. The same note applies to the figures which follow.

Source: WIPO Statistics Database, June 2011.

Figure 4.4 reports the growing share of university and PRO applications from middle- and high-income countries as a share of total PCT applications for three periods starting in 1980.

Figure 4.4: Universities and PROs make up a growing share of PCT filings in middle-income countries

Share of university and PRO applications in total national PCT applications broken down by income group (percent), 1980-2010



Source: WIPO Statistics Database, June 2011.

Among high-income countries, the US has the largest number of university and PRO filings under the PCT with 52,303 and 12,698 filings respectively (see Figures 4.5 and 4.6).[43] The second largest source of PRO applications is France with 9,068, followed by Japan with 6,850.

Among middle-income countries, China leads in terms of university applications with 2,348 PCT filings (see Figures 4.7 and 4.8), followed by Brazil, India and South Africa. The distribution of PRO patent applications is more concentrated. PROs from China (1,304) and India (1,165) alone represent 78 percent of total patents by PROs originating from middle-income countries. They are followed by Malaysia, South Africa and Brazil.

43 The shares are calculated based on the sum of applications for individual countries for the period 1980-2010.

Figure 4.5: US and Japan lead in university PCT applications

University patent applications under the PCT from high-income countries, country shares, in percent, 1980-2010

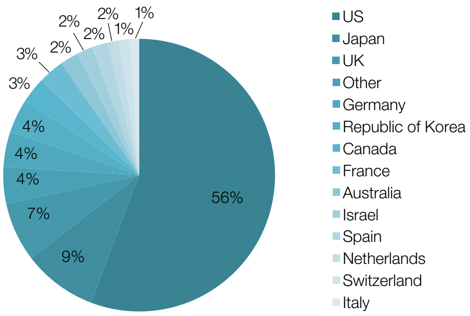
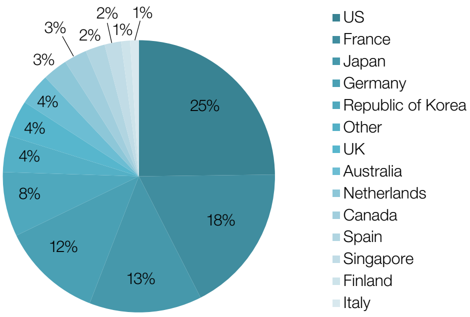


Figure 4.6: US, France and Japan lead in PRO PCT applications

PRO patent applications under the PCT from high-income countries, country shares, in percent, 1980-2010



Note: Some countries have been members of the PCT system for longer than others, which impacts on the comparability of some country shares.[44]

Source: WIPO Statistics Database, June 2011.

The highest rates of university PCT applications as a share of total patents under the PCT are reported for Singapore (13 percent), Malaysia (13 percent), Spain (12 percent), Ireland (11 percent) and Israel (10 percent). The countries with the highest participation of PROs out of total PCT filings are Malaysia (27 percent), Singapore (19 percent), India (14 percent) and France (10 percent).

Figure 4.7: China and Brazil lead in university PCT applications

University patent applications under the PCT from middle- and selected low-income countries, country shares, in percent, 1980-2010

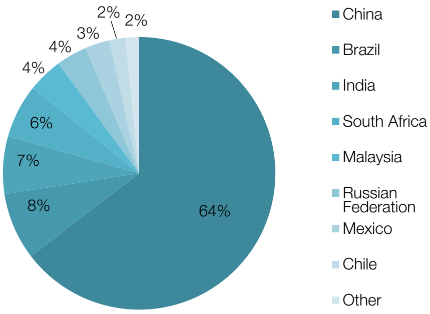
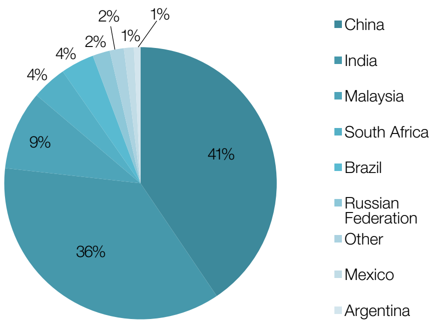


Figure 4.8: China and India lead in PRO PCT applications

PRO patent applications under the PCT from middle-and selected low-income countries, country shares, in percent, 1980-2010



Note: Some countries have been members of the PCT system for longer than others, which impacts on the comparability of some country shares.[45]

Source: WIPO Statistics Database, June 2011.

44 The France, Germany, Japan, the UK and the US (since 1978), the Netherlands (since 1979), Australia (since 1980), the Republic of Korea (since 1984), Canada (since 1990) and Israel (since 1996).

45 Brazil and the Russian Federation since 1978 (date of Ratification of the Soviet Union, continued by the Russian Federation from December 25, 1991), China since 1994, Mexico since 1995, India since 1998, South Africa since 1999, Malaysia since 2006.

Figure 4.9 shows the evolution of PCT applications jointly filed by universities and firms for high- and middle-income countries (see also Annex Figure 4.2). In particular, after 2000, joint filings have been on the rise, including as a share of total university PCT patent applications. In 2010, they made up about 18 percent of all PCT applications from high-income countries involving universities, up from about nil in 1980 and from about 12 percent in 2000.

On average, university-company co-ownership of PCT patents is more prevalent in middle-income (25 percent) than in high-income countries (14 percent); albeit the levels of filings are substantially lower in the former country group. Japan has the highest share of university-company partnerships at 42 percent of all university applications, followed by the Russian Federation (30 percent), China (29 percent) and Brazil (24 percent). University and PRO partnerships are most prevalent in France (50 percent), followed by Spain (22 percent), India (12 percent), Brazil (10 percent), Germany and South Africa (8 percent each).

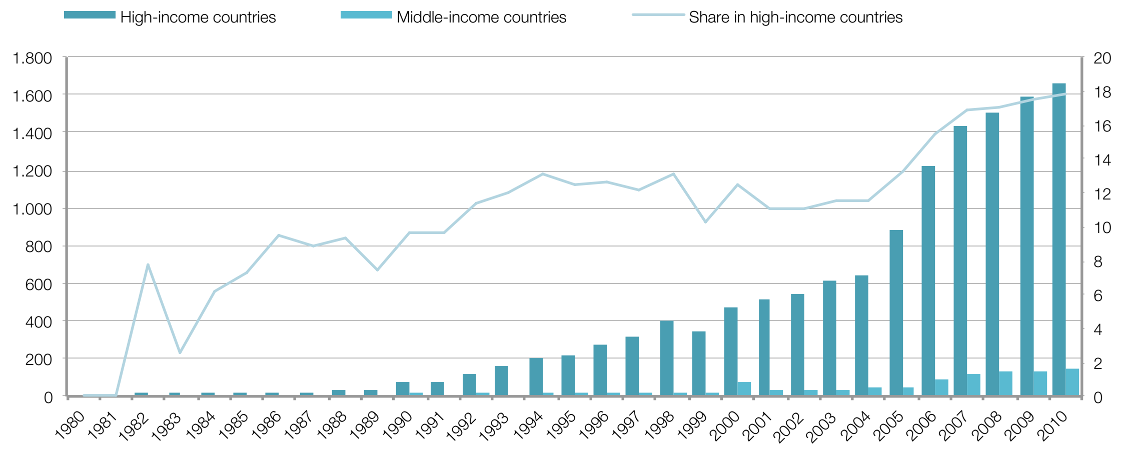
National patent filings of universities and PROs are more heterogeneous

Aside from a few high-income countries, statistics on national patent applications from universities and PROs are largely unavailable. Producing such data is, however, a valuable exercise, given that PCT statistics do not describe the full extent of university and PRO patenting activity. Other than problems related to measurement, the difference in national patenting versus PCT trends could reflect whether universities have a stronger or weaker propensity to file abroad.

Table 4.1 summarizes the numbers of university and PRO resident applications in several countries, for a select number of countries based on a comparable methodology applied by WIPO for this report (see the Methodological Annex). These exploratory data show quite heterogeneous trends across countries, with increases in Brazil, Germany and Italy between 2000 and 2007, and less activity in Israel and the UK.

Figure 4.9: The share of joint university-firm patent applications under the PCT is increasing rapidly

Joint university-firm PCT applications in absolute numbers (left) and as a percentage share of total university PCT applications (right): 1980-2010



Note: "University-firm co-ownership" refers to the situation where there are at least two applicants, one being a university and another being a company. Inventors are not considered. The share of university-firm applications in total PCT applications by middle-income countries are not shown due to their high volatility. Since 2001 this share has been in the range between 16.9 percent and 34.5 percent.

Source: WIPO Statistics Database, June 2011.

Table 4.1: National university and PRO patent filings for selected countries

Resident university and PRO patent applications for selected countries, 2000-2007

Country	Institution	2000	2001	2002	2003	2004	2005	2006	2007
Germany	University	231	240	357	487	509	563	670	647
	PRO	385	396	482	466	589	580	622	618
UK	University	897	942	971	911	770	803	824	734
	PRO	186	192	135	125	72	83	89	83
Brazil	University	60	65	162	176	187	233	246	325
	PRO	20	10	27	39	32	26	25	39
Italy	University	66	108	62	26	139	133	186	197
	PRO	52	78	30	19	35	38	41	21
Israel	University	61	77	112	66	36	21	68	70
	PRO	10	9	13	6	5	4	8	8

Note: These calculations only concern countries for which the Patstat database is reasonably complete for specific years.[46]

Source: WIPO, based on the Worldwide Patent Statistical Database (Patstat) of the European Patent Office (EPO), July 2011.

According to available national reports or studies, resident university and PRO applications in France almost doubled between 1996 and 2004, reaching 724 applications.[47] In Japan, the number of resident university applications filed stood at 7,151 in 2009 (compared to 1,089 in 2000).[48] In the Republic of Korea, 9,980 university resident applications were filed in 2008, a compound annual growth rate of 41 percent since 2000.[49] In China, resident university patent applications grew to 17,312 in 2006, a compound annual growth rate of 44 percent since 2000, representing about 14 percent of total resident applications which is far superior to other countries. Analysis of Chinese university patenting from 1998 to 2008 shows a significant overall increase, making Chinese universities some of the most active in the world. This can be explained in part by government grants to research institutes and to universities filing a large number of patent applications, and related initiatives.[50]

46 The discrepancy between the number of published resident applications (country totals) according to Patstat 2011 and WIPO's Statistics Database on aggregate resident applications filed (for the period 2000-2007) is: -21.8 percent for Germany, -29.2 percent for the UK, -3.1 percent for Brazil, -16 percent for Italy and -17.3 percent for Israel. The WIPO Statistics Database does not provide numbers for Italy for the period 2001-2006.

Patents granted to US universities – which cannot be directly compared to the above figures on application – amounted to between 3,000 and 3,500 per year in the period 1998-2008, and declined from 3,461 in 2000 to 3,042 in 2008 (about 4 percent of total resident patents granted in 2008).[51] US universities started patenting at a much earlier phase and, given the volume of private sector patenting, the university share stands at about 5 percent of total resident patents granted in 2008.

Figure 4.10 depicts the share of university and PRO resident applications out of total national resident applications for selected countries. The countries with the largest share of university applications are China (13.4 percent), Spain (13.2 percent), Mexico (12.6 percent), and Morocco (11.2 percent).[52] The countries with the largest share of PRO resident applications are India (21 percent, based on unofficial data), Mexico (9.5 percent), China (7.2 percent) and France (3.6 percent).[53]

47 See *Inspection générale des finances* (2007). The number excludes filings at the EPO.

48 See Japan Patent Office (2010).

49 See Korean Ministry of Knowledge Economy (2010).

50 See Luan *et al.* (2010).

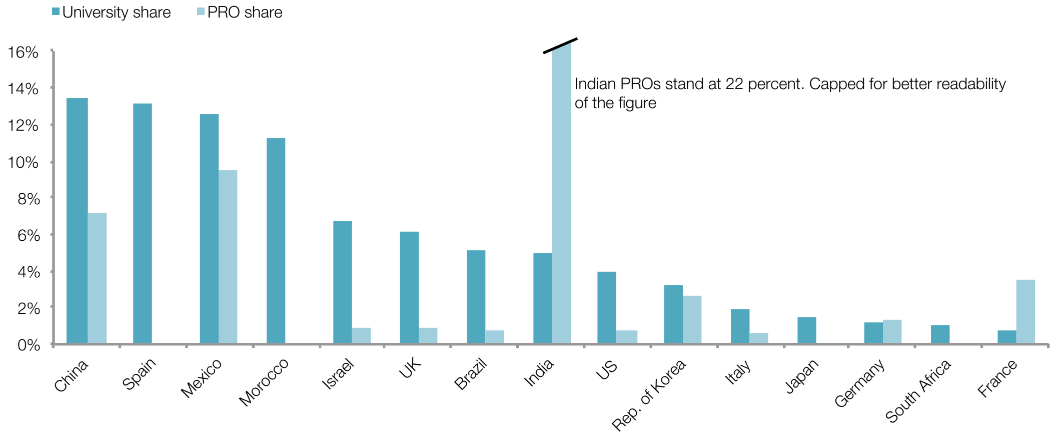
51 See NSF (2010). On average, and for all patents not limited to universities, about 42 percent of applications filed are granted by the United States Patent and Trademark Office (USPTO). See European Patent Office, Japan Patent Office, Korean Intellectual Property Office and USPTO (2009), "Four Office Statistics Report", available at: *www.trilateral.net/statistics/tsr/fosr2009/report.pdf.*

52 It is interesting to compare those numbers with the ones from PCT filings for the same periods. They are almost identical for Spain (14.1 percent), Mexico (7.8 percent), China (5.6 percent) and Morocco (3.6 percent).

53 In comparison, those shares for the same periods for PCT data are 18.3 percent for India, 2.5 percent for Mexico, 2.8 percent for China and 10.3 percent for France. Note that the data for the French report is an average for three years (one before, one after and the reported year).

Figure 4.10: China has the greatest share of national applications from universities while India has the greatest share of applications from PROs (among selected countries)

University and PRO patent applications as a share of total national applications for selected countries (percent), for different time spans



Note: China (2000-2006), Spain (2005-2009), Mexico (2006-2009), Morocco (2008-2010), Israel (2000-2007), United Kingdom (2000-2007), Brazil (2000-2007), India (1990-2007), United States (2000-2008), Republic of Korea (2000-2008), Italy (2000-2007), Japan (2000-2009), Germany (2000-2007), South Africa (2000-2004), France (2000-2004). No data on PRO patenting are available for Japan, Morocco, South Africa and Spain. Direct country comparisons are not advisable as the methodologies and years vary country by country, and because some sources are more reliable than others. The data for India includes patents filed via the PCT.

Source: Various national reports, selected studies reporting unofficial data (notably for India) and Patstat, July 2011.[54]

The large share of Indian PROs in total patent filings and the large share of Chinese universities in total patent filings stand out in the above figures. The trend in China can be linked to strong growth in university patenting over the last decade. In the case of India, the Council of Scientific and Industrial Research (CSIR) – the largest domestic patentee with more than 4,000 patents (from 1990-2007) and over 80 percent of public sector patents – is primarily responsible for the large share of Indian PROs.

54 The Republic of Korea: number of university applications filed, from "Analysis of Technology Transfer," Korean Ministry of Knowledge Economy (2010); total resident applications, from WIPO Statistics Database. Number of resident PRO applications and total number of resident applications used to calculate the PRO share, from Patstat 2011 for the period 2000-2007. According to Patstat 2011 and WIPO's Statistics Database on aggregate resident applications filed (for the period 2000-2007), the discrepancy between the number of published resident applications is -10.6 percent for the Republic of Korea. Brazil, Israel, Italy, UK, Germany: Patstat 2011. France: university and PRO application numbers from Balme *et al.* (2007); number of total applications from WIPO Statistics Database. French patent applications filed at the EPO are not included. Japan: university applications filed, from JPO Annual Report (2010); number of total applications from WIPO Statistics Database. China: all numbers from Chinese National Science and Technology reports from 2007 and 2004. US: university patents granted and totals from National Science Board, Science and Engineering Indicators 2010, for the period 2000-2008. PRO and totals (both granted) used for PRO share, from Patstat 2011 for the period 2000-2007. According to Patstat 2011 and WIPO's Statistics Database on aggregate resident applications granted (for the period 2000-2007), the discrepancy between the number of resident applications granted is 3 percent for the US. South Africa: see M. Sibanda (2007). India: patents by origin, some granted others applications filed, including patents filed under the PCT, all data from Gupta (2008). Mexico: university and PRO applications filed, from INPI Mexico; for the number of total applications, see the WIPO Statistics Database. Morocco: applications filed, data from Office Marocain de la Propriété Industrielle et Commerciale (OMPIC), Rapport annuel 2010. Spain: resident university applications filed, from the Spanish Ministry of Industry, Tourism and Commerce; for total applications filed, see the WIPO Statistics Database.

Technological fields of university and PRO patenting

Overall, university and PRO patenting primarily concerns biomedical inventions and pharmaceuticals, broadly defined. This is true of high-income and other economies alike. The result is not surprising as these industries are the most science-driven. However, whether patenting in these technological fields is demand- or supply-driven is less clear.

On the basis of PCT data, it can be shown that, for the period 1980-2010, university patenting was largely limited to a few fields, including the following major areas for both high- and middle-income countries: biotechnology, with 22 percent of all university applications in high-income countries and 18 percent in middle-income countries; pharmaceuticals, with 15 percent in high- and 14 percent in middle-income countries; medical technology, with 8 percent in high- and 5 percent in middle-income countries; organic fine chemistry, with 6 percent in high- and middle-income countries; and measurement technologies, with 6 percent in high- and middle-income countries.

For PRO applications, during the same period the most prominent technological fields in high-income countries were biotechnology (21 percent), pharmaceuticals (10 percent), measurement technologies (8 percent), organic fine chemistry (5 percent) and analysis of biological materials (5 percent). For middle-income countries, the largest share of PRO applications related to pharmaceuticals (17 percent), organic fine chemistry (17 percent), biotechnology (14 percent), basic materials chemistry (5 percent) and digital communications (5 percent).

The available data on national patent filings – based on Patstat and the WIPO methodology – confirm this trend. For the period 1989-1998, 287 university applications (resident and non-resident) were published by the Brazilian patent office, with the two largest fields being pharmaceuticals and biotechnology.

4.2.3

University and PRO licensing growing but from low levels

Few indicators exist for assessing the scale of university commercialization and related impacts.

The most widely used indicators for measuring university technology transfer are the number of licenses issued and the associated income. These data are only available for a few countries, are often based on non-governmental surveys using varying methodologies and schedules, and are largely confined to universities without covering PROs.

Broadly speaking, the data tend to support the view that university and PRO licenses and related income are growing from low levels. However, outside the US, both are still relatively modest compared to the number of patents filed by public research institutions, or compared to their income from R&D contracts and consulting or their R&D expenditure. Furthermore, while licensing revenue has been increasing, it has been largely driven by a few institutions in a few sectors – notably the pharmaceuticals, biomedical and software sectors – and mostly by a few specific patents. As shown below, however, in particular in Table 4.2, this is diversifying. Finally, universities and PROs often seem to generate more income from non-patent licensing relating to biological materials or know-how and from copyrighted materials.

- Licensing income has grown consistently in both Canada and the US (see Table 4.2, which also notes that this growth is partly explained by the growth in reporting institutions). Five institutions were responsible for 53 percent of all reported licensing income in 1991, 48 percent in 2000 and 33 percent in 2009. In the light of the discussion in Section 4.3 on the impact of exclusive licenses on innovation, it is important to note that the majority of licenses in the US and Canada are non-exclusive (1,682 exclusive versus 2,595 non-exclusive licenses in the US, and 177 out of 317 in Canada, both for 2009).

Table 4.2: Canadian and US university technology transfer: 1991-2009

Year	1991	2001	2002	2005	2006	2007	2008	2009
Reporting institutions (Canada/US)	9/841	27/169	31/181	33/180	39/182	37/187	35/184	36/175
Number of licenses and options[55] executed								
Canada				570	462	675	620	690
US				4,648	4,678	4,882	4,993	5,214
Licensing income (in million US dollars)								
Canada	3.3	42.1	32.8	43.7	56.6	58.6	53.9	52.1
US	162.2	1,039.3	1,175.3	1,927.3	1,854.0	2,656.4	3,410.4	2,277.7

Note: As shown above, the number of reporting institutions has grown throughout the selected time period and, in particular, in the 1990s. The totals shown reflect the growth of reporting institutions plus growth in the number of reporting universities. Aside from universities, the above numbers also cover hospitals and research centers, but exclude institutions that reply anonymously.

Source: Statistics Access for Tech Transfer (STATT), database of the US Association of University Technology Managers (AUTM), May 2011.

- According to a survey of Australia, the amount of income from licenses, options and assignments stood at USD 246 million in 2009.[56] One patent filed by the Commonwealth Scientific and Industrial Research Organization generated the majority of this income.

- According to a survey of Switzerland, about half of institutions surveyed provide data on licensing income, which amounted to USD 7.55 million in 2009.[57]

- According to a survey of Spain, the number of licenses executed grew to 190 in 2007, and income increased from about EUR 1.69 million in 2003 to EUR 1.98 million in 2007.[58]

- In France, the amount of licensing revenue is reported to be modest and concentrated in a few patents and institutions. It has not grown much since the commercialization of university technologies became a declared policy objective in the late 1980s.[59]

On average, university and PRO licensing income is still marginal compared to total university and PRO funding or research expenditure. Table 4.3 shows the ratio of licensing income per dollar spent on R&D. The small size of licensing revenue in Europe in comparison to the US has been highlighted.[60] However, this is also related to measurement issues concerning the identification of university and PRO patents (see Box 4.3) and different approaches to technology transfer.[61]

55 An option agreement gives potential licensees a certain amount of time to evaluate the technology and to discuss and arrange a licensing agreement.

56 Based on the OECD exchange rate for 2009: Australian Dollar (AUD) 1.282 for USD 1. See Commonwealth of Australia (2011). Seventy-two publicly-funded research organizations responded to the survey, including universities, medical research institutes, publicly-funded research agencies. Definitions as per the report: "A license agreement formalizes the granting of IP rights between two parties where the owner of the IP (the licensor) permits the other party (the licensee) to have access to and the right to use the IP. An option agreement grants the potential licensee a period during which it may evaluate the IP and negotiate the terms of a licensing agreement. An assignment agreement conveys all rights, title and interest in and to the licensed subject matter to the named assignee." The data for Europe are derived from the Association of European Science and Technology Transfer Professionals (ASTP) survey. It is similar to the AUTM and NSRC surveys and covers approximately 100 research institutions from up to 26 European countries.

57 Based on the OECD exchange rate for 2009: Swiss Francs (CHF) 1.086 for USD 1. The respondents to the survey were 7 cantonal universities, 2 federal institutes of technology, 6 universities of applied sciences and 3 related research institutions in the ETH domain. About half of the participants in the survey provided data on licensing income.

58 See RedOTRI (2008). The Spanish Network of University Knowledge Transfer Offices (RedOTRI) provides information on Spanish university inventions. In 2007, the network had 62 member universities. There were 44 valid answers on royalties from licenses for 2007.

59 See *Inspection générale des finances* (2007).

60 See Conti and Gaulé (2011).

61 *Idem.*

Table 4.3: Ratio of income from "IP licenses, options and assignments" to total research expenditure, 2000 to 2009

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	2.8	2.0	1.9	1.6	1.3	1.3	2.1	3.6	1.5	4.1
Canada	1.8	2.3	1.6	1.6	1.4	1.2	1.4	1.2	1.0	-
Europe	-	-	-	-	3.2	3.2	0.4	1.0	1.3	-
UK	0.6	1.1	1.1	1.1	1.5	1.3	1.3	1.4	2.1	-
US	4.8	3.4	3.5	3.4	3.4	5.3	5.3	5.5	6.6	6.5

Note: The methodology is described in the report below. See footnote 56 for definitions. Here, "Europe" includes 26 countries but not the UK.[62]

Source: Commonwealth of Australia (2011).

In middle- and low-income countries, data on university technology transfer are even scarcer. All existing studies, however, point to the nascent stage of IP and its commercialization which is limited to a few patents and patenting institutions.[63]

The scarcity of information also suggests that patents are used much less for technology transfer, due in part also to a lack of a culture and institutions supporting formal IP-based technology transfer in these countries, and weak research activity with few technology applications. Also in these countries, other forms of IP and know-how are more commonly used to transfer knowledge to businesses.

- A study surveying selected Latin American universities reports that 17 out of the 56 universities surveyed in Argentina, Brazil, Colombia, Chile and Mexico have licensed some type of IP.[64] This mostly concerns designs, know-how or secrets, rather than patents.

- In China, 8.7 percent of patents granted to higher education institutions were licensed out in 2007, contributing only a minor share to total revenue but, admittedly, representing a very large figure in absolute terms.[65] One study concludes that patent licensing is underutilized, compared to the very large amount and the high growth of Chinese university patenting (see Section 4.2.2).[66]

- In South Africa, most universities received no revenue from their patents, other than the Council for Scientific and Industrial Research, the University of Johannesburg and North-West University.[67]

Table 4.4: Technology transfer activity by Chinese higher education institutions, 2000-2007

	2000	2001	2002	2003	2004	2005	2006	2007
Number of patents licensed and sold	299	410	532	611	731	842	701	711
as a percentage of patents granted to higher education institutions	45.9	70.8	76.3	35.3	21	18.9	11.3	8.7
as a percentage of university R&D revenue	2.3	2.6	1.7	2.3	1.5	1.3	1.1	1.4

Source: Wu (2010).

62 The European data are derived from the Association of European Science and Technology Transfer Professionals (ASTP) survey, which is similar to the AUTM and NSRC surveys. The ASTP survey covers about 100 research institutions from up to 26 European countries. Where reported, the ASTP data exclude UK institutions.
63 See Dalmarco and Freitas (2011).
64 See PILA Network (2009).
65 See Wu (2010).
66 See Luan *et al.* (2010) and Sibanda (2009).
67 See Sibanda (2009).

4.3

Assessment of impacts and challenges in high-income countries

A large body of economic literature has assessed the efficiency and impacts of university patenting in high-income countries. Research now also focuses on PRO patenting.

The studies aim to identify the impacts of increased university IP technology transfer and examine the optimal design of policies and the institutions that carry them out. A first set of studies has mapped various linkages between universities and industry and explored the use of patents in such transactions.[68] Since then, a second stream of research has moved from universities and firms to a more disaggregated level, often studying the effects of patenting on the behavior of individual academics.

4.3.1

Direction of impacts

The literature is divided as to the impacts of IP-based technology transfer laws and practices.

Conceptually, the question is whether an exclusive system based on university patenting is the optimal approach for driving business innovation and, at the same time, preserving the science system.[69]

The various impacts discussed in the literature are set out in Tables 4.5 and 4.6. They distinguish possible benefits and costs for the two respective main agents – firms and public research institutions – and broader systemic impacts on science, the economy and society.

On the one hand, economists have argued that allowing universities and PROs to patent inventions enables them to "reveal their inventions" while improving incentives for firms to develop and commercialize them further, and creating a "market" for university and PRO inventions.[70]

The rationale behind this argument is that inventions developed by universities are often embryonic and need further development in order to be useful. Firms will be reluctant to invest in further development if these inventions and the resulting products can be appropriated by third parties, as well as if there is legal uncertainty regarding the ownership of results. In many cases, they will want to obtain an exclusive license. For universities and PROs, the benefits may include increased revenue, more contractual research and greater cross-fertilization between entrepreneurial faculty and industry. TTOs or other intermediaries lead to a division of tasks by undertaking IP administration and commercialization, thus contributing to a new form of technology market. This IP-based technology transfer is meant to lead to a better use of research results, different forms of academic entrepreneurship and therefore improved economic and social development.

68 See Gulbrandsen *et al.* (2011).
69 See Foray and Lissoni (2010).
70 See Mowery *et al.* (2001).

This can bring about the following benefits (see also Tables 4.5 and 4.6):

- For universities, this set-up can lead to (i) increased IP ownership, facilitating academic and other entrepreneurship (including academic spin-offs) and vertical specialization; (ii) cross-fertilization between faculty and industry; and (iii) increased student intake and ability to place students in firms.
- For firms, it (i) facilitates the revelation of useful university inventions to the business sector; (ii) enables the creation of a market for inventions based on publicly-funded research; and (iii) can spur the commercialization of new products generating profits and growth.
- Positive systemic outcomes could include (i) increased impact of more research with the potential for application; (ii) improved innovation system linkages; (iii) a higher quality of research and education, in particular for science; (iv) greater commercialization of inventions; (v) positive impacts on entrepreneurship and local jobs; and (vi) for the wider economy, greater competitiveness in the global market.

On the other hand, it has been argued that patents are not necessary to provide incentives for university scientists and engineers to invent and to disclose inventions. It is also argued that university and PRO patents do not necessarily facilitate the collaboration between public research institutions and firms.[71]

According to this view, 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 which contribute to cumulative learning. The patenting of university inventions and related conflicts of interest might, however, have negative influences on these norms; slow the diffusion of university inventions, including research tools; and stifle innovation.[72] The exclusive licensing of patents to single firms might, in particular, limit the diffusion of knowledge generated with public funds.

Table 4.5: Impacts of IP-based technology transfer policies on universities/PROs and firms

	Potential benefits	Potential costs (or investment)
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 the revelation of useful university inventions to the business sector** • 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) **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

71 See David (2004) and Dasgupta and David (1994).

72 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.

Critics also suggest that IP-based technology transfer by research institutions limits the diversity of research that would otherwise be pursued by follow-on innovators. The decline in the intensity and diversity of research has made for rather minimal income prospects for institutions themselves. Moreover, a strong stance on IP by universities and PROs might negatively impact other knowledge transfer channels – such as informal knowledge exchanges with the private sector and fellow scientists, as well as more formal R&D collaboration – due to the complexity of negotiating IP rights.

The following costs may arise (see also Tables 4.5 and 4.6):

- For universities, this set-up can lead to (i) a diversion of time away from scientific research; and (ii) IP-related establishment and maintenance costs (which can howere also be seen as an investment).

- For firms, this could result in (i) potential barriers to access of university inventions; and (ii) increased IP-based transaction costs and tensions in industry-university relationships.

- Negative systemic impacts could include (i) a reorientation of the direction of research towards less diversity and an overemphasis on short-term, commercially-oriented research; (ii) negative impacts on open science; (iii) prospects of reduced government funding for public research, for science and for the economy more widely; (iv) long-run negative effect of diverting attention away from academic knowledge production; (v) long-run negative effects of IP on open science and follow-on innovation; and, finally, (vi) the fact that IP might inhibit rather than promote commercialization of inventions.

Table 4.6: Systemic impacts of IP-based technology transfer policies

	Potential Benefits	Potential costs
Broader impacts on science	**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**	**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**
Innovation and growth	**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**	**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**

4.3.2

Impacts and experiences in high-income countries

This section sets out the key lessons learned from the experiences of high-income countries and the associated economic literature.[73]

The evidence confirms the potential benefits mentioned in the previous subsection. University and PRO patenting and efficient technology transfer policies and institutions are an important precondition for increasing opportunities for commercializing university inventions (see Table 4.5). Access to early stage university research is critical to firms, in particular in the science-intensive sectors. Turning university ideas into innovation requires substantial development by the private sector and the involvement of academic inventors, lending credence to the motive behind such patent-based policies.[74]

The evidence also suggests a synergy among a wide range of traditional academic, entrepreneurial and patenting activity of scientists as well as interaction with the private sector.[75] It also confirms the complementary nature of the different technology transfer channels. Firms that actively engage with public research institutions, both through informal exchanges – such as at scientific conferences – and formally-organized knowledge exchanges – such as in R&D collaboration – are also likely to license more inventions from universities. They may also engage intensively with faculty to further develop inventions as the tacit knowledge involved in an invention is important in turning it into a commercial innovation.

Yet, the literature and information on past experiences do not easily lend themselves to a complete cost-benefit analysis of the above impacts, which could be easily generalized across sectors and countries with very different characteristics. The literature does not send an unambiguously clear message on the most adequate ownership model, i.e., whether the university-ownership model is superior to one in which faculty retains ownership of inventions, or to other models.[76] Finally, the long-term implications of patenting on science are also still under discussion.

One reason for this incomplete cost-benefit analysis is that these policies, institutional practices and their implementation are still relatively young, in particular outside the US.

In addition, however, two other interrelated factors complicate the evaluation of policy initiatives aimed at IP-based university technology transfer.

i) Definitional and measurement challenges: So far, mostly IP-based indicators have been used to evaluate university technology transfer. However, surveys of patenting and licensing activity – undertaken by national governments, multilaterally, or by PROs themselves – are rare.[77] Often they tend to underestimate the number of university inventions and the broader impacts of university technology transfer (see Box 4.3).[78]

73 See Baldini (2006) and Larsen (2011).
74 See Goldfarb *et al.* (2011); Goldfarb *et al.* (2001); and Jensen and Thursby (2001).
75 See Boardman and Ponomariov (2009).

76 Kenney and Patton (2009) argue that the university-ownership model is neither optimal in terms of economic efficiency nor for advancing the interest of rapidly commercializing technology and encouraging entrepreneurship. They maintain that this model is plagued by ineffective incentives, information asymmetries and contradictory motivations for universities, inventors, potential licensees and university TTOs. These structural uncertainties can lead to delays in licensing, misaligned incentives among parties and obstacles to the flow of scientific information and the materials necessary for scientific progress.
77 See OECD (2003).
78 See Aldridge and Audretsch (2010).

Furthermore, the drivers of successful commercialization of academic research – whether via licensing or an academic spin-off – and the different vectors of university-industry knowledge transfer are numerous. However, no framework exists for measuring and evaluating these knowledge transfers, their interactions and the role of various policies to spur them on.[79] In this data context, and given the unique conditions of particular institutions and countries, the ability to draw clear causal conclusions concerning the effect of a particular IP-based technology transfer policy on the commercialization of academic research or on wider economic indicators is limited. Furthermore, caution needs to be exercised in generalizing particular case-specific findings to other institutions, disciplines or countries.

ii) Benchmarking against appropriate alternatives: It is vital to benchmark outcomes resulting from new IP-based technology transfer policies against realistic alternatives or a careful assessment of the status quo. Often, new outcomes are benchmarked against scenarios that entail a perfect "open science" system with rapid knowledge diffusion and strong incentives to innovate. Arguably, in most cases the policy alternatives are less favorable. For a start, the science system itself is also prone to malfunction, in particular with regard to internal communication and its efficacy in helping to spur innovation, and the resulting economic and social development. Furthermore, with or without IP-based technology transfer models, the linkages between different actors in national innovation systems are rarely perfect and mostly deserve policy attention.

Moreover, the introduction of formal IP ownership models for universities and PROs is often not responsible for the formation of IP rights to begin with. To the contrary, their objective is to further clarify existing IP ownership in order to facilitate follow-on transactions. Specifically, the alternative, existing settings are often of the following nature: (1) unclear ownership rules lacking incentives to further develop inventions, as was previously the case in high-income countries and as is still often the case in less developed economies; (2) governments own the title to inventions emanating from publicly-funded research, as was previously the case in the US; (3) faculty members own the title, as was previously the case in Europe; or (4) particular firms solely own the title resulting from joint university-industry projects. Compared to the introduction of IP-based technology transfer practices, these scenarios mostly provide less legal certainty as to ownership of inventions and offer less potential for innovation as firms will neither be aware of nor interested in developing these inventions further.

With these caveats in mind the next subsections portray the evidence for wider economic impacts, the factors determining a successful IP-based university and PRO technology transfer system, and the evidence regarding the most severe concerns with respect to such a model.

Evidence for wider economic impacts

Policy-makers in many high- and middle-income countries alike are lamenting the fact that too little innovations result from the growing number of university and PRO patents.

It is important to move beyond the number of patents filed and licensing revenue earned as measures of success in technology transfer.

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

As desirable as this is, the contribution that commercialization of university IP makes to economic development is hard to demonstrate convincingly in economic studies. The calculations are plagued by the same issues that complicate impact assessments of public R&D (see Box 4.1 and the previous section), i.e., constructing data that effectively capture other dimensions of the impacts of IP-based technology transfer is challenging (for example, productivity gains of downstream firms using or building on such IP, or a consumer surplus from the resulting innovation). Establishing clear causal relationships between IP-based technology transfer and these social gains is even harder. Only one study, prepared for an industry association, aims to assign figures to wider economic impacts in the US.[80]

Given the above difficulties, many related studies show impacts of university-industry interactions, without necessarily implying that technology transfer based on IP, or for that matter the university-IP ownership model, is the essential condition and trigger for this impact.

The literature shows that university-industry technology transactions can generate important spillovers by stimulating additional R&D investment, new firms and products, and job creation.[81] Benefits for firms include an increase in the level of applied research effort, higher overall R&D productivity as measured by patents, a higher quality of patents, the introduction of new products, increased sales and labor cost reductions. Linkages with industry are shown to have enriching effects for university research and also lead to synergies between applied and basic research and the development of new research ideas.[82]

Beyond this, studies have used the limited statistics on the number of academic spin-offs directly or indirectly linked to IP-based commercialization efforts of TTOs to evaluate IP-based technology transfer legislation (see Box 4.5). Given the generally low figures, some observers have used these data to cast doubt on the overall impact of such policies.[83]

Yet, these absolute numbers might miss out on the truly important question of which start-ups produce tangible economic results and improve employment in the medium- to longer-run. Studies show that university patenting and licensing have been fundamental to the emergence of new industries, such as the scientific instruments industry, semiconductors, computer software and the nano- and biotechnology industries.[84] Several major corporations originated from academic start-ups facilitated by TTOs.[85] US university start-ups also seem disproportionately more likely to develop into viable businesses and to create more jobs.[86] For instance, the US AUTM collects case studies and examples of university IP contributions over the last 30 years, with 423 start-ups still operating as of the end of 2009, in particular in the health care sector.[87] 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.[88] Again, attributing these positive impacts exclusively to IP-based technology transfer is most likely not appropriate.

80 See Roessner *et al.* (2009), cited in AUTM (2010). This widely cited study states that, over the last 30 years, more than 6,000 new US companies were formed on the basis of university inventions; 4,350 new university-licensed products entered the market; and these inventions made a USD187 billion impact on the US gross domestic product, with 279,000 jobs created. The authors argue that no attempt was made to valuate the other significant economic contributions of university-based research, and that estimates are therefore considered to be significantly conservative.

81 See Rosenberg and Nelson (1994).

82 See Azoulay *et al.* (2006) and Owen-Smith and Powell (2003).

83 See Aldridge and Audretsch (2010).

84 See Rosenberg and Nelson (1994) and Zucker *et al.* (1998).

85 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).

86 See Di Gregorio and Shane (2003) and Shane (2004).

87 See AUTM (2010).

88 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.

Box 4.5: Academic entrepreneurship stimulated by university inventions

The same surveys that produce data on licenses for a few countries (see Subsection 4.2.3) also report on the creation of spin-offs. Table 4.7 shows Canadian and US data. The frequency of TTO start-up activity varies significantly across universities. Some universities routinely transfer their technology through the formation of new firms, while others rarely generate start-ups. Moreover, rates of start-up activity are not a simple function of the magnitude of sponsored research funding or the quantity of inventions created.

Table 4.7: Creation of Canadian and US university start-ups, selected years

Year	1996	2001	2002	2003	2004	2005	2006	2007	2008	2009
Canada	46	68	49	57	45	36	31	48	39	48
US	199	424	393	352	436	437	534	544	584	585

Note: The number of reporting institutions has grown throughout the selected time period, contributing to some upward movement in the figures. Beyond universities, the above numbers also cover hospitals and research centers.

Source: Statistics Access for Tech Transfer (STATT), AUTM, May 2011.

In Australia, 19 start-up companies based on research commercialization were created in 2009. In Spain, 87 start-up companies were created in 2003, and 120 in 2007. The Swiss Technology Transfer Association reports that 66 new start-ups were created in 2009, 45 involving a transfer of IP and 21 using the know-how of the research institution. A study that surveyed a select number of Latin American universities reports that 11 out of the 56 universities had created a spin-off.

Importantly, the involvement of a university or a PRO in the creation of firms or licensing will depend on their technology transfer strategies, and which channels are prioritized to commercialize technology. The creation of firms requires not only the participation by researcher, under clear and appropriate incentives, but also the involvement of surrogate entrepreneurs.

Success factors for harnessing the knowledge from public research

Successfully transferring inventions from universities to businesses is a resource-intensive and complex undertaking. Various policy and other factors need to coincide to ensure that laws spurring university and PRO patenting bear fruit.

At the country level, the positive impact of university technology transfer based on patenting will largely depend on the broader technology transfer environment, in particular: 1) sound research capabilities and human capital; 2) the broader legal and regulatory framework; 3) the institutional setting of research institutions, their governance and autonomy; 4) access to finance; and 5) the absorptive capacity of firms. It is also critical to preserve the diversity of other knowledge transfer channels between universities and firms.

At the institutional level, a sizeable amount of literature exists on the following success criteria, only some of which are under the control of universities and policymakers:[89]

- 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 being more active than public universities, for instance;
- the portfolio of disciplines, some of which are more prone to patenting than others;
- the research quality of the institution, its reputation and network;
- the extent of existing collaboration with a university and its entrepreneurial climate;
- organizational practices and an institutional culture which foster IP-based technology transfer;
- the establishment of institutional strategies for knowledge transfer and commercialization;

89 See Belenzon and Schankerman (2009).

- competitive faculty salaries and incentives to file for IP rights and to disclose inventions to a TTO, notably also with respect to whether patents are considered in the attainment of academic tenure;
- the characteristics of the relevant TTO (see Box 4.6);[90] and
- 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. The often volatile and skewed licensing income typically does not recover these costs. As a result, the idea that licensing could act as a potential substitute for other university income or other funding sources should be discarded.

Box 4.6: The role of technology transfer offices and open questions

The activities TTOs undertake can exclusively be confined to IP management and commercialization; or, alternatively, they can have a broader scope and also conduct activities related to regional economic development, the funding of education, and industry training in areas such as IP and technology transfer.[91]

The nature and type of technology transfer intermediaries are important factors influencing the technology transfer performance of universities.[92] The size and age of a TTO, the number of its staff, their experience (in particular in industry) are major success criteria for building a qualitative portfolio of inventions. However, these attributes are not a guarantee of success. Experience shows that building successful TTO interfaces between science and industry is a challenge even in the high-income countries with the most technology transfer experience.

Open questions include:

1) What is the optimal degree of involvement of scientists in the development of an idea, and should inventors have the option to select commercial providers?
2) How can the danger of "capture" of TTOs by industrial interests or specific firms be avoided?[93]
3) To what extent should a TTO be the only body able to commercialize university inventions? Should researchers be obliged to go through a TTO or also be able to manage and commercialize IP on their own?[94]
4) Given the costs involved, should universities have an individual TTO? Several institutions are experimenting with regional or sectoral TTOs, recognizing that many individual universities or PROs do not have the necessary scale for their own TTOs.

Beyond these factors, 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.[95] Well-defined university policies with clear rules on benefit sharing improve performance by giving researchers incentives to participate in the transfer of technology.[96] Rules that help to standardize relationships with potential licensees through standard forms and contracts also reduce transaction costs in finalizing agreements with the private sector. In addition, these policies can help address some of the concerns raised above, ensuring that universities and PROs – and their faculties – do not neglect their other major missions of teaching and research in the name of commercialization.

90 See Belenzon and Schankerman (2010).
91 See Zuñiga (2011), Sections 3 and 5.
92 See Debackere and Veugelers (2005); Owen-Smith and Powell (2001); Lach and Schankerman (2008); and Chapple *et al.* (2005).
93 See Owen-Smith and Powell (2001).
94 A "Free agency" approach, according to which faculty members choose who will negotiate licensing agreements for them while promising a share of income to the university, could be an alternative to TTOs or relevant competition.
95 See Debackere and Veugelers (2005).
96 See Lach and Schankerman (2008).

Substantiating the concerns about publicly-funded research

Table 4.6 describes a spectrum of concerns about the impact of IP-based technology transfer on the science system and on relationships between universities, PROs and firms.

The empirical literature has, however, been narrowly focused on gauging the impacts of university patents on the publication activity of scientists. Indeed, the existing studies are also severely limited, because metrics on the broader impacts on science are hard to come by. Thus, the literature stresses "the ambiguous nature of current empirical evidence on the long-term implications of academic enterprise".[97]

In any case, the available evidence does not lend itself to exaggerated concerns with respect to impact. In fact, the opposite is true.

1) Impacts on scientific publications and the norms of "open science" in academia: The majority of studies focusing on the relationship between publishing – the proxy used for open science – and patenting have found little evidence of conflict between interactions with industry and traditional academic roles.[98]

On the contrary, the studies conducted in the US and Europe find a positive relationship between interactions with the private sector, patenting and publishing. In fact, scientists who have research contracts with industry demonstrate superior productivity, both in terms of number and quality of publications as measured by citations, compared to their non-inventing peers.[99] Academic patenting may well be complementary to publishing at least up to a certain level of patenting output, after which some studies find a substitution effect.[100] This evidence is interpreted to show that no substantial shift towards applied research is taking place.[101] It is argued that scientists are likely to publish results even if they are also patented, because of the continuing importance of publishing in establishing priority and reputation in academia. Also, new research – especially, but not only, in the biomedical field – may be dual-purpose, both basic, in that it uncovers new scientific principles, and commercially applicable, perhaps even commercially motivated.[102]

Interestingly, the evidence on whether the establishment of an academic spin-off has an adverse effect on scientific output is less clear and somewhat mixed. Some studies find that faculty entrepreneurs are more productive, while others see a decrease in publishing, subject to variations by field.

Substitution effects between patenting and publishing may arise under specific circumstances, notably where researchers have already achieved a prominent scientific career; at high levels of patenting; and, in some cases, where academics are involved in corporate patents.[103]

Nevertheless, the above results which suggest that a positive relationship between publishing and patenting could be influenced by the sample of respondents and some inherent statistical problems related to endogeneity. This could simply mean that the best scientists happen to be good at publishing, attracting public and private research funds, and patenting at the same time. Alternatively, it could mean that cooperation with industry positively influences both publishing and patenting, but that one neither causes nor influences the other.

97 See Larsen (2011); Engel (2008); and Geuna & Nesta (2006).
98 See, for good overviews Grimaldi *et al.* (2011); Fabrizio and Di Minin (2008); and Czarnitzki *et al.* (2009).
99 See Thursby and Thursby (2011).
100 A few studies have also established a positive relationship between licensing and publishing activity. Jensen *et al.* (2010), for instance, show that the ability to license their university research will lead scientists to devote more time to university research and less time to consulting on applied projects with firms.
101 See Thursby and Thursby (2007).
102 These fall under what has been referred to as "Pasteur's quadrant" in Stokes (1997).
103 See, for instance, Crespi *et al.* (2010); Czarnitzki *et al.* (2011); and Gulbrandsen *et al.* (2011).

Furthermore, this evidence depends on the scientific discipline in question, and the positive relationship is strongest in fields such as biomedicine and the life sciences, i.e., in research motivated by both a quest for fundamental understanding and considerations of use.

Finally, these findings say little about potential publication delays or violations of open science principles. Surveys of scientists have indeed 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.[104] Examples have been noted of companies restricting the findings of university researchers or researchers denying others access to their data.[105] Despite these examples, no broad evidence exists that could unambiguously demonstrate alarming impacts and that, moreover, would causally link such behavior to faculty patenting activity. Increased secrecy is often also a consequence of greater industry collaboration as well as other factors. Nonetheless, this is an important area for future study. Policy approaches to mitigate these potential effects are needed.

2) Impacts on basic research: Insofar as this can be measured, the existing literature – mostly focused on the US and the life sciences – finds neither a decrease in basic research nor an effect on the ratio of applied versus basic research as a result of patenting.[106] It has been shown that the great majority of licensed university inventions require substantial effort by firms to develop commercially viable products from them. According to the literature, this is a clear indication that university research continues to be fundamental in nature.[107] The literature also shows that commercially-oriented research may be complementary to more fundamental research.[108] The positive feedback loops running from firms to universities, and for the benefit of science, may indeed be underappreciated.

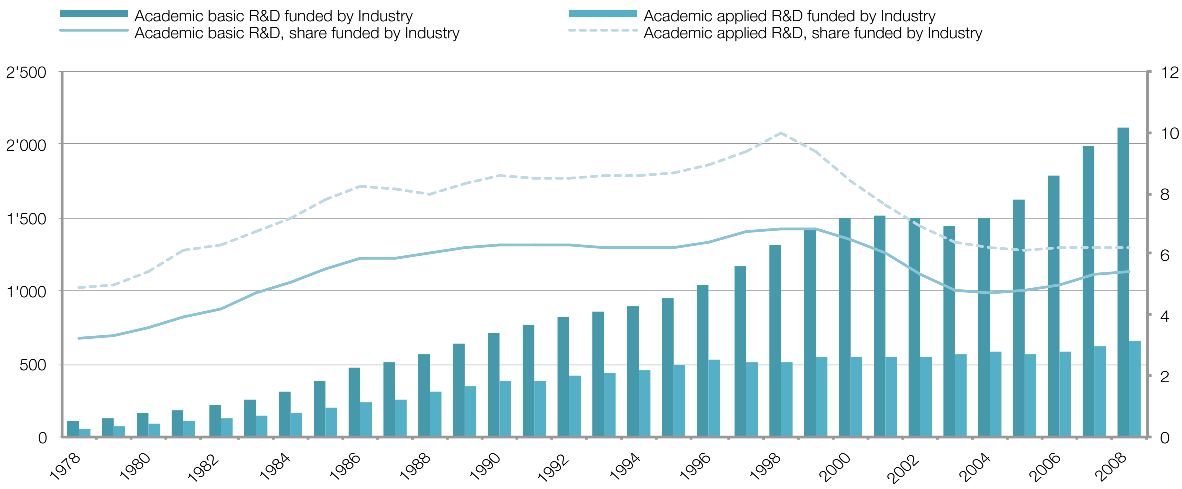
To put these findings into perspective, the data show that universities continue to account for the majority of basic and academic research, while pursuing little development. If anything, basic R&D as a percentage of gross domestic product (GDP) has increased or remained the same over time, including in high-income economies.[109] Also, the risk of industry exerting an overly great influence might be exaggerated as it funds only a small share of academic R&D. In the US, for example, companies finance about 5 to 6 percent of basic and applied academic R&D, respectively, with a focus on basic R&D (see Figure 4.11).

This evidence notwithstanding, it remains a complex task to distinguish between, and separately measure, basic research, applied research and development activity. In any event, the whole breakdown may be misleading if there are important feedback effects from later stage research that may affect earlier stage research.

104 See, for an overview of this literature, Azoulay *et al.* (2009).
105 See, for instance, Campbell *et al.* (2002); Campbell *et al.* (2000); and the related literature.
106 See Rafferty (2008) and Larsen (2011).
107 See Rafferty (2008).
108 See Breschi *et al.* (2007); Van Looy (2006); and Van Looy *et al.* (2004).
109 OECD Main Science, Technology and Industry Statistics (MSTI).

Figure 4.11: Industry funding of US basic and applied academic R&D, 1978-2008

in current USD million (left) and as a percentage of total university applied and basic R&D (right)



Note: Data for 2008 are preliminary.

Source: WIPO, based on data provided by the National Science Foundation (NSF).

3) Impacts on the diversity of research: More and more university patents contain scientific references, which raises the question whether universities are increasingly patenting elements of science rather than technological results derived from research.[110] Yet it has been argued that the openness of upstream research encourages higher levels of downstream research as well as new research directions. Patenting by public research institutions might hamper this openness (see Table 4.6).

The evidence on this is unsatisfactory and mixed. On the one hand, studies show that scientists have not stopped pursuing a line of research because of third-party patents on research input.[111] On the other hand, a recent study finds that restrictions on scientific patenting may have negative impacts on the diversity of research (see Box 4.7). Also, in another study, the citation rate for particular papers declines after a patent is granted on the ideas they discuss. This is taken as evidence for a subsequently reduced ability of researchers to draw upon that knowledge in an unrestricted fashion.[112] Both of these studies focus on biomedical technologies where applied and basic research overlap and holdup situations are more likely than in other disciplines.

Another concern is that universities or firms do not have access to or are forced to license expensive tools, and that this would create barriers to entry in a particular field of scientific research. More research is warranted to substantiate this and to determine whether existing research exemptions would prevent firms and universities from circumventing related patents.[113]

110 See Sampat (2006).

111 See Walsh *et al.* (2005).

112 See Murray and Stern (2007).

113 One issue is that, depending on the country in question, research exemptions provide different degrees of flexibility in this regard. The exemptions, at times, also do not clearly seem to cover research tools, as opposed to other patented inventions.

Box 4.7: Of mice and academic freedom

A recent paper tests the issue of whether restrictions on scientific openness – such as those created by university patenting – may limit diversity and experimentation in basic research itself. The authors use the example of certain genetically-engineered mice and related scientific papers to examine the effects of more relaxed IP policies following an agreement between the private sector and the US National Institutes of Health (NIH). Specifically, that agreement eased IP-based restrictions limiting access to research materials (the mice) and limitations on downstream expropriation by follow-on innovators. In particular, the authors evaluate how the level and type of follow-on research using these mice changes after the NIH-initiated increase in openness.

The authors find a significant increase in the level of follow-on research driven by a substantial increase in the rate of exploration of more diverse research paths. They interpret this to mean that openness of upstream research does not simply encourage higher levels of downstream exploitation; it also increases incentives for additional upstream research by encouraging the establishment of new research directions, and an increase in more basic and higher quality research publications. The authors suggest that the effects of university IP legislation should be studied in the light of these findings.

Source: Murray *et al.* (2009)

4) Influences on university and industry relations: Anecdotal evidence from the US suggests that proactive university efforts to own results of co-sponsored research and to generate licensing income have become controversial (see Table 4.5).[114] 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.[115] Some frustration stems from the fact that universities may tend to 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 (see Chapter 2).[116]

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.

When looking at official statistics, one cannot help observing modest but continued industry-university collaboration, measured in terms of the share of industry-funded R&D carried out in academia. Specifically, the share of higher education R&D expenditure financed by industry has always been small, but increases when looking at averages for all Organisation for Economic Co-operation and Development (OECD) countries (from 2.9 percent in 1981, to about 6.6 percent in 2007).[117] In Argentina, China and the Russian Federation, for example, firms also fund a stable or increasing percentage of academic R&D.

Finally, and as mentioned in Chapter 1, when dealing with universities, firms are also increasingly inventive with regard to their IP policies, fostering cooperation on the one hand while ensuring control on the other. For instance, university researchers are granted access to the company's internal IP, for example antibody libraries and research tools, and, in certain cases, are allowed to publish in addition to obtaining external funding.

114 See Thursby and Thursby (2007) and Litan *et al.* (2008).

115 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).

116 See So *et al.* (2008).

117 OECD MSTI.

4.4

IP-BASED TECHNOLOGY TRANSFER AND THE CASE OF LOW- AND MIDDLE-INCOME COUNTRIES

Few studies exist on the challenges and impacts of academic technology transfer in low- and middle-income countries.[118] Two main themes can be identified: (i) the impacts of technology transfer legislation enacted in high-income countries on less developed countries – the international dimension (see Subsection 4.4.1); and (ii) the impacts of the nascent home-grown technology transfer legislation of middle- and low-income countries – the domestic dimension (see Subsection 4.4.2).

Table 4.13 summarizes the various dimensions of the potential impacts.

The possible benefits to be derived from the IP-based technology transfer of academic inventions tend to be the same as for high-income countries, except that poorer countries can theoretically benefit from public R&D spill-overs from high-income countries, without necessarily investing large amounts in public R&D themselves. In addition, strengthening patents in these countries may also shift the research interest in high-income countries towards projects with relevance to markets in less developed economies.

However, the ability to benefit is critically dependent on the less developed country's aptitude – in particular of firms – to produce and absorb science despite a potentially weaker scientific and industrial base. Either domestic firms or locally present multinationals can take on the role of further developing university and PRO inventions. The potential costs are also the same as mentioned above, except that they could be heightened by greater resource constraints and the greater reliance on knowledge of more developed economies. In this context, it has been argued that would be easier for public research institutions and firms in developing countries to access such knowledge when it is not protected.

Table 4.13: Impacts on low- and middle-income countries

Potential benefits	Potential costs
1) All the same benefits mentioned above (see Tables 4.5 and 4.6) • This depends, however, on the capacity to absorb and further develop university inventions – either by domestic firms or by locally present multinational firms – and on whether these inventions are at all relevant to low- and middle-income country needs **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	**1) All the same above-mentioned costs (see Tables 4.5 and 4.6), 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

118 The above effects are more significant with regard to sectors in which large amounts of patents are owned by universities and non-profit research institutions. In agriculture, almost a quarter of patents are owned by universities and non-profit research Institutions. See Graff (2003).

4.4.1

Impacts of high-income countries' technology transfer legislation on low- and middle-income economies

The literature on this topic has focused on how technology transfer legislation originating in high-income countries impacts on low- and middle-income economies.

In that context, the literature considers their reduced and more expensive access to knowledge.[119] One concern is that the patenting of scientific results in high-income countries could restrict access to research tools, databases and technologies.[120] 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 particular life-saving medications (see Section 4.5 in this regard, which suggests policies to counteract such impacts).[121]

At the outset, the impacts of reduced access to such knowledge are critically dependent on whether the university or PRO inventor has been granted a patent by the national patent office of the country in question.[122] Also, the costs depend on whether (i) the technology is at all meaningful to the country and (ii) whether such country has the ability to take up and develop unpatented university inventions prior to such legislation in the first place.

That said, more research is required on this potential downside effect. The earlier sections of this chapter show that the number and share of university and PRO patents are growing and, in particular, in the pharmaceutical and health area. It would be of interest to determine which patents are filed in areas critical to low- and middle-income economies and their related effects, including the terms of access and impacts on consumption. The extent to which research in high-income countries focuses on neglected diseases or crops for the tropics – areas of great interest for less developed countries – and the extent to which this research is being patented is likely to be limited. Yet this question deserves more research. It would also be interesting to ascertain which safeguards could be put in place to avert the possible downside effects of university and PRO patenting (see Section 4.5).

Finally, the literature considers the potentially harmful impact of international knowledge diffusion that could be triggered by increased university and PRO patenting in high-income countries. The concern is that opportunities for scientific networking between scientists in high-income and less developed countries might be narrowed.[123] Examples have been cited of cooperation agreements between institutions of more and less developed countries being abolished due to across-the-board patenting strategies.[124] In particular in the climate change debate, less developed countries have called on high-income countries to make the results of publicly-funded research in this area available. In the absence of more systematic evidence, it is of central importance to further substantiate concerns of faltering scientific cooperation between richer and poorer countries that could be linked to IP, and a corresponding decline in scientific openness.

119 Kapsynski *et al.* (2003) cite major HIV treatment drug patents held by Yale University, the University of Minnesota, Emory University and Duke University.
120 See Boettiger and Benett (2006); So *et al.* (2008); Montobio (2009); and Engel (2008).
121 See Boettiger (2006).
122 Sampat (2009) explains that for university patenting in the North to affect access to drugs in middle- and low-income countries, two things need to be true: universities would have to own a substantial number of patents; and, second, universities or firms licensing university technologies would have to file patents in low-and middle-income countries.
123 See Clemente (2006).
124 *Idem.*

4.4.2

Challenges to home-grown technology transfer in low- and middle-income countries

Despite costs and benefits similar to high-income countries, low- and middle-income economies' differing needs must be taken into consideration in formulating technology transfer policies and anticipating their related impacts.

Experience and the economic literature show that different stages of development and different innovation systems require different policies in order to promote IP-based incentives for the commercialization of public research.[125] Conditions for technology transfer develop over time and depend heavily on research capabilities and science-industry linkages. Having a broad view of the concept of technology commercialization, looking at intermediate steps and broad technology transfer activities – not exclusively focused on IP creation and licensing, and academic entrepreneurship – makes for good policy advice.

The importance of improved science-industry linkages in low- and middle-income economies

Low- and middle-income countries vary substantially with regard to the R&D capacity of their public research institutions, science-industry cooperation and their infrastructure and policy framework for technology transfer (see Chapter 1 and Subsection 4.2.1).

Generally speaking, however, a key difference with high-income countries is the weak linkages between public R&D and national economic development which is often rooted in the factors below:

- a lower level of science and technology activity (S&T);
- the fact that the government and international donors are often the main funders of S&T, and that national PROs are the main R&D performers (see Subsection 4.1.1), implying low research and innovation capabilities of firms;
- less developed human capital for S&T activity, particularly a low number of scientists in firms and the best domestic scientists moving abroad ("brain drain" effect);
- lower quality research and low relevance of public research to the business sector;
- limited science-industry linkages, explained by a low absorptive capacity of firms combined with an ensuing lack of "business" demand for S&T;
- a lack of policies and structures to facilitate academic and other start-ups; and
- constrained access to financing as a barrier to the development of innovation.

Linkages between PROs and the business sector are constrained by a number of structural factors and inertia. In many less developed economies, government-funded S&T expenditure has largely focused on agriculture and overlooked engineering and industrial research. The lack of applied research, the deficit of trained engineers and applied scientists, and weak technological capabilities in the manufacturing sector are all factors contributing to a disconnection between science and firms.

125 See Guellec *et al.* (2010).

Structural features have also constrained the development of linkages between universities and firms. Often, commercial activity by universities and researchers has been or is still highly regulated or forbidden. With few exceptions, most universities fully depend on federal budgets and have weak linkages with regional governments and economies.

The lack of absorptive capacity in firms and their natural focus on imitative innovation and acquisition of foreign technology as innovation strategies also contribute to fragmentation in national innovation systems (see Chapter 1).[126] The technological strategies of firms in lower- and middle-income economies often depend on off-the-shelf imported technology, primarily in the form of machinery and turnkey technology transfer from abroad. Often these are also the only options for these firms to access current technology.[127] The barriers to industry-science collaboration reported by firms include a lack of communication channels with universities, differences in organizational culture (in respect of timing and product delivery), uncertainty of a market perspective for research results, and high costs for developing and commercializing university research.[128]

In this context, technology transfer policies that are not accompanied by policies targeting the strengthening of R&D capabilities in firms and industry-science linkages will unlikely be successful. Similar as in the case of high-income countries, transforming academia into more entrepreneurial institutions requires cultural change – in particular among researchers, and often increased university autonomy, including for more competitive hiring and in terms of resource management.

Compared to high-income countries, the following are additional barriers to technology transfer in low- and middle-income countries:

- lack of clear university and PRO technology transfer policies;
- weak operative guidelines on patenting, for example on disclosure and commercialization of IP at the institutional level;
- little awareness about and few incentives for researchers to participate in IP-based technology transfer; and
- absence of or inadequate resources for TTOs, with staff lacking the necessary skills and experience related to IP and commercialization.
- more generally, an additional friction to the development of IP registration and commercialization in many middle- and low-income countries is the sluggish process of patenting at national patent offices and its relatively high cost.[129]

However, these characteristics are not shared equally across all low- and middle-income countries. For the most part, work is ongoing to improve the systemic weaknesses in national innovation systems and giving increasing autonomy to universities. As evidenced earlier, many of these countries are also in the midst of implementing or setting up technology transfer policies and practices (see Subsection 4.2.1). Indeed, in some cases this has already led to significant impacts, both in terms of measured technology transfer and the related broader impacts on public research institutions, firms and the linkages between them.

Finally, it is also important to reiterate that high-income countries struggle with many of the same challenges when it comes to putting in place functioning technology transfer practices. Therefore, a perfect blueprint that could easily be adopted does not exist.

126 See Navarro *et al.* (2010).

127 See Zuñiga (2011). In Argentina, for example, according to the innovation survey of 1998-2001, 84 percent of firms that cooperated with other actors in the national innovation systems did so for informational purposes and 58 percent for training purposes; only 21 percent engaged in cooperation for R&D. In Colombia, the percentages of firms (within those that reported links with agents providing technological services) are 31, 50 and 15 percent, respectively.

128 For evidence from China on this, see Guan *et al.* (2005).

129 See Zuñiga (2011).

4.5

New university policies act as safeguards

The preceding discussion pointed to possible downside effects of university and PRO patenting on knowledge diffusion and access to technology or critical products.

Better monitoring and improved understanding of these potential effects would seem to be desirable.

Furthermore, policies and practices are being tested by governments and universities to institute safeguards against unintended negative consequences.

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

- First, the patenting and the licensing of particular inventions and technologies 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, 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.[130] 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").

Related codes of practice aim to prevent abusive patenting and licensing:[131]

- As of 2004, the European Commission suggested guidelines and established a recommendation based on various expert groups.[132]
- A nine-point plan has been set up by a group of academics and endorsed by a number of US universities which provide safeguards (see Box 4.8). This plan is particularly concerned with the preservation of follow-on science and innovation, and with ensuring that patents do not create undue burdens. One of the nine points stresses that patenting universities should be sensitive to poor countries, in particular with respect to their medical and food needs.
- A number of prominent US institutions have also endorsed a "Statement of Principles and Strategies for the Equitable Dissemination of Medical Technologies".[133]
- Legislation and practices that facilitate or guarantee humanitarian access for poorer countries to technologies and products based on publicly-funded research are being established.[134]

130 See OECD (2003) and So *et al.* (2008).
131 See Montobbio (2009); OECD (2003); and Sampat (2009).
132 See MacDonald *et al.* (2004) and European Commission (2008, 2009).
133 *www.autm.net/Content/NavigationMenu/TechTransfer/GlobalHealth/statementofprincliples.pdf* (accessed on October 11, 2011).
134 See Chokshi (2006) and Chokshi and Rujkumar (2007).

Box 4.8: "Nine Points to Consider in Licensing"

- Universities should reserve the right to practice licensed inventions and to allow other non-profit and governmental organizations to do so.
- Universities should also endeavor to structure licenses, especially exclusive licenses, in ways that promote investment, technology development and use, with milestone criteria to back up such requirements.
- Universities should strive to minimize the licensing of "future improvements".
- Universities should anticipate and do their best to manage or eliminate technology transfer-related conflicts of interest.
- Universities should try to ensure broad access to research tools.
- Enforcement action should be carefully considered.
- Universities should be careful to avoid working with private patent aggregators (referred to as non-practicing entities in Chapter 2) whose business model is limited to asserting patents against established firms rather than seeking to promote further development and commercial application of the technology.
- In cases where there is a market for the sale of unlicensed patents, universities should try to ensure that purchasers operate under a business model that allows for commercialization rather than a model based on threats of patent infringement litigation to generate revenue.
- Universities should try to anticipate which technologies may have applications that address important unmet social needs unlikely to be served by terms appropriate for commercial markets and to structure agreements to allow for these applications. The examples are technologies suited to meeting the agricultural, medical and food needs of less advanced countries.

Source: Drawing on Merrill & Mazza (2010), based on the informal White Paper "In the Public Interest: Nine Points to Consider in Licensing University Technology", March 6, 2007 *http://otl.stanford.edu/documents/whitepaper-10.pdf*.

Moreover, universities and PROs are trying a number of interesting additional approaches (see Table 4.12). These include patenting strategies but also access to research tools and to copyrighted works such as teaching materials, an often neglected IP issue in this debate.

Table 4.12: University and PRO "open IP policies"

Licensing strategies	• A preference to grant companies non-exclusive rather than exclusive licenses[135] • Universities discriminate in issuing licenses, making them free or cheaper if used for humanitarian, not-for-profit purposes[136] • Free licenses to small companies or start-ups for selected technologies • Instituting favorable licensing strategies to promote access by poorer countries
Access to copyrighted materials	• Free access to research materials, publications and teaching materials • Open source or, more recently, open hardware licenses[137]

To conclude, the extent to which these policies are implemented and successful in reaching their intended goal is an issue for further research. Governments, including in low- and middle-income countries, that are in the process of adopting technology transfer laws and policies can consider formally instituting such safeguards.[138]

135 See Nill (2002).

136 Examples are: the University of Leuven not requiring royalties on Tenofavir from drugs sold in countries that belong to the Gilead Access Program; Yale University negotiating humanitarian terms with Bristol Myers Squibb for sales of drugs in Africa; University of California, Berkeley, with several licensing agreements for humanitarian purposes.

137 European Organization for Nuclear Research (CERN) open hardware license: *www.ohwr.org/projects/ohr-support/wiki/Manifesto.*

138 See So *et al.* (2008).

4.6

Conclusions and directions for future research

Policymakers increasingly seek to bolster the effectiveness of academic research in fostering innovation. In this context, universities and PROs have been encouraged to patent their inventions and license them to the private sector. Technology transfer policies and institutions have been put in place to facilitate this knowledge transfer. This approach of commercializing publicly-funded research aims to enable firms to better identify and further develop inventions based on academic research, thus generating wider economic and social benefits.

As a result, the number of national and international patent applications by research institutions has been increasing, in particular in fields such as biotechnology and pharmaceuticals. The licensing income generated is still relatively modest and concentrated within a few institutions, but it is growing fast and diversifying.

Based on the available evidence, this chapter concludes that IP-based technology transfer policies and institutions are instrumental to increasing opportunities for the commercialization of academic inventions. The evidence also suggests a synergy between academic and entrepreneurial activity and the complementary nature of different knowledge transfer channels. That said, the chapter has also discussed potential costs of such initiatives.

Moreover, the evidence shows that simply instituting relevant laws and regulations is only a first ingredient to stimulating industry-science linkages. A number of conditions need to be in place at the country and institutional level to reap the resulting benefits. Moreover, diverse stages of development will require different approaches and complementary policies, including safeguards for avoiding the downside risks of university patenting. A blueprint that could easily be adopted across institutions and countries therefore does not yet exist, even in high-income economies.

Areas for future research

In the light of the discussions in this chapter, the following areas emerge as promising fields of research:

- The interactions between IP-based knowledge transfer channels and other vectors need more careful analysis; this concerns, in particular, the question whether and where they are substitutes rather than complements.

- Based on better search algorithms and targeted institutional surveys, better data are required to clearly identify patents, licensing income and spin-offs derived from academic research, and benefits from faculty involvement. The role of IP in transforming a scientist into a successful entrepreneur deserves particular attention. The respective impacts of licensing university technologies to existing firms versus the creation of academic spin-offs is also of interest.

- Experiences related to making technology transfer institutions efficient should be documented more widely, in particular with an eye for lessons applicable to lesser endowed research institutions. Examples include the design of university policies, the design of performance incentives for researchers and the most optimal interface between public research and firms. The question whether the current approach of "one-size-fits-all" laws and practices suits the different scientific disciplines – on the supply side – and industrial sectors – on the demand side – needs to be explored.

- More compelling studies are needed to demonstrate the economic benefits of IP-based technology transfer, and the benefits of the university-ownership model in particular. Quantifying the missed opportunities resulting from a lack of incentives to commercialize, in particular in low- and middle-income countries, would be equally desirable.

- Work is required to better document the potential negative effects of IP-based knowledge transfer on the broader science system. The design and implementation of policy safeguards which are emerging should be monitored and evaluated. At the same time, the positive feedback loops on the science system from industry-science linkages deserve more attention.

- Finally, analytical work with respect to low- and middle-income countries is only now emerging, as the majority of these countries are just starting to implement associated policies and as many of these countries may not have much innovation capacity in the interim to experience the impact of such mechanisms.

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DATA ANNEX

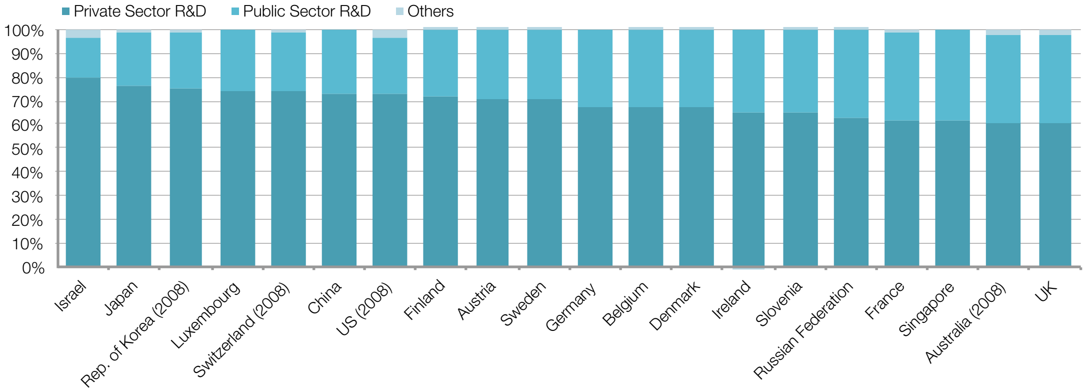
Table A.4.1: Technology transfer frameworks and legislation in selected low- and middle-income economies

	Law/Policy/Decree entitling ownership & inventor rights	Innovation and related policies	Inventor compensation	Mandatory TTO creation
Brazil	Ownership: 1996 Patent Law (Law 9279) Inventors: 1998 Law on Industrial Property (Art. 93): maximum of one-third of the value of the invention	2004: Innovation Law (Law No. 10.973) Incentives for R&D, collaboration and technology transfer	**YES** 5% to 33% of royalties or licensing income	**YES** At each institution or shared among institutions
Russian Federation	Ownership: 1998 Decree and 2003 Revision of the Patent Law	2007-2012: R&D in priority fields of science and technology development in the Russian Federation for 2007–2012 2002: Technology Transfer Network	**NO**	**NO** Not mandatory but encouraged
India	Ownership: 2000 Governmental Ruling Inventors and clarification of ownership rules: Utilization of Public Funded Intellectual Property Bill 2008 (under approval)		**YES** At least 30% of licensing income	**NO** Not mandatory but encouraged
China	Ownership: 2002 Measures for Intellectual Property Made under Government Funding (entitling patenting) Inventors: S&T Findings Conversion Law	1998: the S&T Advancement Law and the S&T Findings Conversion Law 2002: Opinion on Exerting the Role of Universities in S&T Innovation	**YES** Varies according to type of transfer	**NO** Not mandatory but encouraged
South Africa	Ownership: Patent Law Ownership and inventors: 2010 IPfrom Publicly Financed R&D Act	National Research and Development Strategy (R&D Strategy)	**YES** At least 20% of licensing income	**YES** Mandatory
Other countries				
Argentina	Ownership: 1995 Law of Patents of Invention and Utility Models (Joint ownership by the university and the centralized agency CONICET)	1995: Law on National Higher Education 2002: National Program for the support and fortification of university linking with industry	**YES** Up to 50% (patent law)	**NO**
Chile	Ownership: 1991 Industrial Property Law	National Innovation Plan	**NO** (statuary rules left to institutions)	**NO** National TTO
Malaysia	Ownership and inventors: 2009 Intellectual Property Commercialization Policy for Research & Development Projects Funded by the Government of Malaysia	Second National Plan for Science and Technology Policy 2002-2020	**YES** Varying shares according to value of revenue	**YES** For public sector R&D institutions
Mexico	Ownership: 1991 Industrial Property Law Inventors: Federal Law of Labor and Innovation Law of 2010	2002 Science and Technology Law 2010 Innovation Law: inventor compensation and TTOs	**YES** Up to 70% of income	**YES** Not mandatory but encouraged
Nigeria	Ownership: 2004 Scheme of Service for Nigeria's Federal Research Institutes, Colleges of Agriculture and Allied Institutions	Guidelines on Development of Intellectual Property Policy for Universities and R&D Institutions	**NO** (recommended; left to institutions)	**YES**
Philippines	Ownership and inventors: 2009 Technology Transfer Bill	1997: Magna Carta for Scientists, Engineers, Researchers, and other S&T Personnel in the Government (for researchers at PROs) and 2002: National Science and Technology Plan	Only available for governmental institutions 60% (PRO)-40% (inventor)	**NO** National TTO (1997)

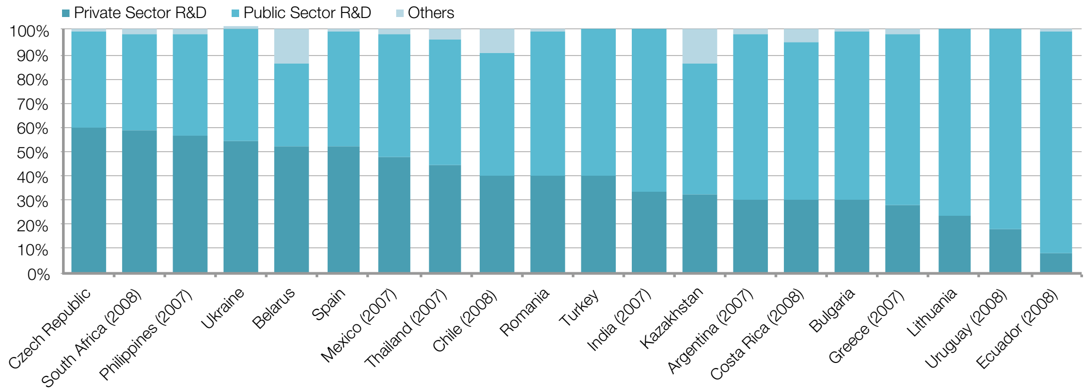
Source: Zuñiga (2011) and WIPO.

Figure A.4.1: Share of public sector in total R&D, high- and middle-income economies

Share of public sector in total R&D in high-income countries, in percent, 2009 or latest available year



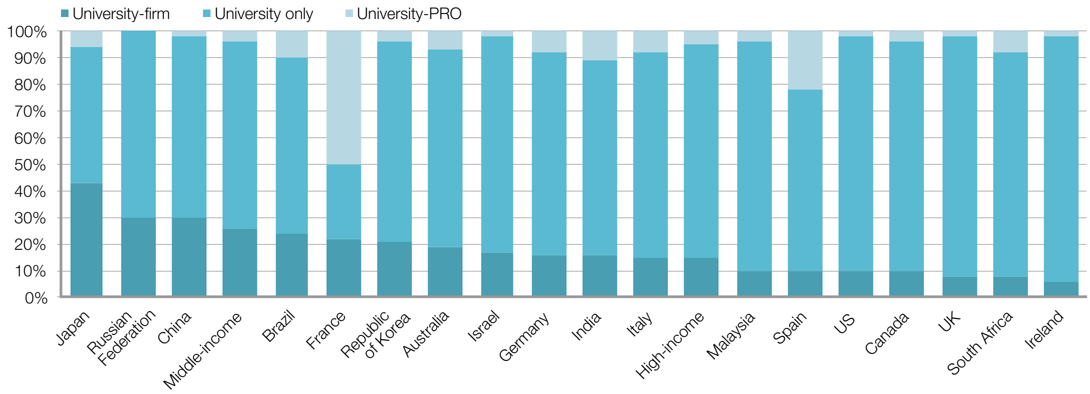
Share of public sector in total R&D in middle-income economies, in percent, 2009 or latest available year



Note: Total R&D is composed of R&D conducted in the private sector (business sector R&D), the public sector (government and higher education R&D), and others (private non-profit and not specified R&D).

Source: WIPO, based on data from UNESCO Institute for Statistics, Eurostat and OECD, September 2011.

Figure A.4.2: Share of joint university-firm and university-PRO applications out of total university PCT applications: 1980-2010, in percent



Source: WIPO Statistics Database, June 2011.

METHODOLOGICAL ANNEX

Counting university and PRO patents in filings under the PCT

PCT records do not classify applicants by institutional category. To count the number of university and PRO applications, one needs to identify applicants and assign them to a category. This is done by searching the names of applicants or their addresses as recorded in patent documents, and determining, based on the name, whether the applicant is a university, PRO, company or an individual.

WIPO's Statistics Database contains PCT application data. Upon filing, an applicant is classified as an individual or non-individual. The following procedures have been used to categorize PCT applicants as a university[139] or PRO: as a first step, the names of non-individual applicants were consolidated in order to obtain a standard name for each. Next, a list of keywords identifying universities, university hospitals and PROs was compiled. In the final phase, manual checks were performed to ensure that applicants were classified correctly. Where in doubt about the classification, a web-based search was performed for additional information. One should note that, in the chosen methodology, applicants are classified according to their names only, without considering their employment relationship or address. Therefore, where a natural person is identified as the applicant filing on behalf of an educational institution, that application would not be classified as belonging to a university.

A similar search method has been developed at the Catholic University of Leuven (Belgium).[140] It also relies on information contained in the applicant's name and, with the help of a list of keywords, assigns applicants to a category. A notable difference in assigning an application to a country is that Leuven's method uses every applicant's country of origin whereas, in the method described above, only the first applicant's country of origin is used. This could potentially lead to a downward bias in the contribution of low- and middle-income countries to academic patenting.

The performance of the two search methods has been compared for countries with at least 4,000 PCT applications over the period 1990-2010. Some differences emerge, with the WIPO method reporting greater shares of both university and PRO applications. This can be attributed to differences in classification of organizations with the definitions and interpretations varying country by country, and/or to the use of different data sources.

Counting university and PRO patents in national patent filings

Data on national patent applications are generally difficult to obtain for a larger group of countries on a consistent and comparable basis. Showing such data is, however, a valuable exercise, because international applications filed through the PCT system capture only a small proportion of a country's total patenting activity, and they underestimate the activity of non-PCT members such as Argentina and other Latin American countries. Most reliable statistics originate from national patent offices or government institutes which track patent applications or patents granted. Frequently, however, a given measurement approach may differ from that of a reporting institution in another country, making cross-country comparisons difficult.

An additional source of national patent applications data is the Patstat database compiled by the EPO. Due to missing data for some countries and years, it is more challenging to analyze and especially to compare country patent output at the national level. The data provided here should be read with caution and seen as an attempt to provide a broader overview of country patenting activity that goes beyond PCT applications.

139 The university category includes all types of educational establishments (e.g., university, colleges, polytechnics, etc.).

140 See Du Plessis *et al.* (2010).

As was done for PCT data, Patstat does not classify patent applicants in groups that separate individuals from institutions or that show institutional affiliation. In order to identify universities and PROs, one would need to perform a search that relied entirely on applicants' names. Certain words – like "university", "college", "school", "government", or "ministry" – in various languages can help to identify institutions. An extensive list of such keywords forms the basis of the search method for identifying universities and PROs in the Patstat database.

Through direct contact with government officials, and by consulting government websites and university directories, lists of universities for 54 countries were carefully checked, and keywords that help identify universities were selected.[141] Through the same approach, lists of PROs for 38 countries were compiled from which, again, keywords identifying PROs were selected.[142] Scopus is a database containing citations and abstracts for scientific journal articles. The top 200 publishing institutions in 62 countries[143] (out of a total of 12,400 institutions) were identified from that database. In addition, the list of keywords and institutions was enriched by using the SIR World Report (2010), which provides a list of top publishing institutions in the world – 2,833 in total.

Several quality checks have been performed. Two issues emerge when producing university and PRO numbers from Patstat: first, the reliability of the data and, second, the reliability of the search method itself, or how well it identifies those institutions. The first question can be addressed by comparing Patstat values on aggregate applications per year per country of origin to aggregate numbers reported to WIPO by national patent offices. WIPO conducts an annual survey of national patent offices' data on patent applications filed. Patstat collects data on applications published. A small discrepancy between the two groups – filed versus published – can be expected, the first being always larger, since some applications are withdrawn and never published.

To verify how well the search method identifies institutions, the results are compared to government reports for selected countries, wherever available.

It is important to note that the country assigned to an application is the country of residence of the first applicant. Data are classified either by origin – all applications with the first applicant originating from that country – or by office – all applications filed in that country. Data by office are broken down into resident applications (filed by individuals or institutions originating from that country) and non-resident applications (filed by individuals or institutions from abroad).

141 Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Bulgaria, Canada, Chile, Colombia, Cuba, Czech Republic, Denmark, Egypt, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, Iceland, India, Indonesia, Iran (Islamic Republic of), Ireland, Israel, Italy, Japan, Republic of Korea, Luxembourg, Malaysia, Mexico, Netherlands, New Zealand, Nigeria, Norway, Philippines, Poland, Portugal, Russian Federation, Serbia, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, UK, Ukraine, US, Uzbekistan, Venezuela.

142 Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Czech Republic, Denmark, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, UK, US.

143 Albania, Algeria, Argentina, Armenia, Australia, Azerbaijan, Bangladesh, Barbados, Brazil, Canada, Chile, China, Colombia, Cuba, Denmark, Egypt, Ethiopia, Finland, France, Germany, Ghana, Hungary, India, Israel, Italy, Jamaica, Japan, Jordan, Madagascar, Malaysia, Mexico, Morocco, Mozambique, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, Poland, Republic of Korea, Romania, Russian Federation, Saudi Arabia, Senegal, Singapore, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, UK, US, Uruguay, Uzbekistan, Viet Nam.