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THE STATE OF PATENTING AT RESEARCH INSTITUTIONS IN DEVELOPING COUNTRIES: POLICY APPROACHES AND PRACTICES

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The State of Patenting at Research Institutions in Developing Countries: Policy Approaches and Practices

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Abstract

By granting universities and public research organizations (PROs) the rights to their own intellectual property (IP) - patents, copyrights, trademarks, utility models, industrial designs - derived from state-financed research, and allowing them to commercialize their results, governments seek to accelerate the transformation of scientific discoveries into industrial applications, and to strengthen collaborative ties between the universities and industries. This study reviews the experience of advanced countries and discusses the opportunities and challenges offered by patents to foster technology transfer from government funded research institutions in developing countries. It presents a review of policy frameworks and recent policy changes aimed to foster academic patenting and technology transfer in low- and middle-income countries. It then analyzes patenting activities by universities and PROs and compares these trends with respect to high-income countries. This analysis is complemented with an assessment of the current state of patenting and technology commercialization practices in a selected group of technology transfer offices (TTOs). We finally discuss policy implications and the challenges developing countries face to build effective technology transfer systems and take full benefit of patents and other intellectual property rights.

JEL Classification: I23, O31, O34

Key Words: Universities, patenting, public research, technology transfer, licensing.

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EXECUTIVE SUMMARY

The use of intellectual property (IP) has increasingly been seen as an attractive instrument for accelerating technology transfer from science to industry, and facilitating industry-science ties through firm creation, licensing and research alliances. Legislative reforms, the growing importance of science for technological innovation and changes in the way governments allocate funds have all contributed to the promotion of IP protection by public research organizations (PROs) and universities and the rise of market oriented activities by universities and research institutions worldwide. These policy trends are in large part inspired by the emergence of high technology districts, the dynamism of academic spinoffs in the United States (US) and the well-built industry-science collaboration that characterizes its national innovation system.

Middle- and low-income countries have started to mirror these international policy trends. In particular, the demand for universities to engage into technology transfer activities, "the third mission", has increased. Yet the use of IP policies to foster technology transfer from government-funded research institutions requires a set of pre-conditions, and is part of a broader set of institutional instruments necessary for technology transfer to take place. It also demands careful design and implementation of the policies. Policy makers and institutions considering IP as instrument to enhance the impact of science on the economy should make a realistic assessment of the state of their research and innovation systems and identify the role that IP – the opportunities and costs - can play in such development.

This study reviews experiences from advanced countries and discusses the opportunities and challenges offered by IP to foster technology transfer from government funded research institutions in developing countries. In particular, we focus our attention on academic patenting. The main findings are the following:

General lessons:

- Middle- and low-income countries differ widely in their research and technological competences, governance of research systems, and more broadly, in their level of economic development and culture of innovation. The potential for patents to play a role in fostering technology transfer increases as countries develop their research capabilities, increase their level of development and improve the general conditions for innovation.

- The international experience shows that IP can provide mutual benefits for research institutions and firms, as well as contribute to generate systemic effects in the economy. Technology transfer through patent licensing, collaboration and firm creation can entail a greater cross-fertilization between faculty and industry, synergies in research and new ideas for science, avoiding wasteful duplication of efforts, and create employment and new market opportunities for firms.

- Patenting of scientific inventions influences the systemic process of technology transfer. It may not only affect the diffusion of new ideas and innovation, but also the progress of science and innovation. Although the evidence suggests that scientific performance by researchers is compatible with technology transfer activities, the evidence is inconclusive with respect to the overall implications on the progress of innovation. The latter calls for precautionary and smart design of IP policies with appropriate policy safeguards.

- Countries and institutions face the challenge to provide adequate incentives for IP creation and technology transfer while preserving the accomplishment and quality of traditional missions such as education and training. A balance must be guaranteed through institutional rules for time involvement, performance evaluation and rules to manage conflict of interest.

- Technology transfer needs special organizational arrangements in order to deploy third mission activities. Technology transfer offices (TTOs) serve as intermediaries between the university and the external environment, and are proven mechanisms to enhance technology commercialization and entrepreneurship. The deployment of TTOs requires long term financial support and commitment by authorities. In addition, their organizational modality and governance may vary according to resource constraints and local needs.

What does IP based technology transfer entail at the national level?

- High level research competencies with potential for industrial applications.

- Clear regulatory policy framework on IP ownership. Policies are not an automatic solution but they help to clarify regulatory frameworks, reduce asymmetries across stakeholders, provide certainty to industry and raise awareness of the importance of technology commercialization.

- Industry-science linkages and communication (interaction mechanisms).

- Technology transfer skills and support to infrastructure (institutional, regional, public/private. search of partners, assistance in IP creation and transactions, and IP contracting.

- Firm absorption and innovation capabilities.

- Access to finance.

At the institutional level, what does an IP based technology transfer approach entails?

- Clear IP and technology transfer policies at universities and PROs.

- Institutional policies providing appropriate incentives to inventors and TTO staff, as well as the strategic approach given to the valorization of research are fundamental to the creation of a proactive environment for technology transfer.

- IP policies should define responsibilities and rules along the process of IP creation and management: IP and disclosure obligations, patenting rules and exemptions, commercialization, firm creation, research exemptions, norms to deal with conflict of interest and policy safeguards.

- IP policy also means consideration of open innovation practices, research and patentability exemptions, and explicit and operable safeguards to protect public interests.

- Cultural change and openness to industry, a strong leadership by directives, and the adoption of a strategic approach to technology transfer are fundamental in the promotion of IP for innovation and technology transfer at research institutions.

The current state of patent activity and technology commercialization at research institutions in low- and middle-income countries:

- Policy frameworks in middle-income countries are mirroring international policy trends in the vesting of IP ownership rights to research institutions and institutionalizing incentives for researchers. These reforms take different shapes: national decrees, ministerial laws, reforms to common law (patent law or employment laws), and explicit IP policies for technology transfer, and/or national guidelines for IP management and codes of conduct.

- Countries that have enacted national decrees or laws stipulating that universities have the right to ownership of research results include: China (1996; 2002), Brazil (1996; 2004), and Mexico (2009). South Africa, Malaysia and Philippines have adopted explicit technology transfer laws to provide the innovation system with institutional instruments through which to develop a unifying policy of technology transfer (previously lacking or misarticulated). By standardizing IP practices and providing incentives for technology transfer, these policies intend to systematize industry-science linkages and lay the foundations for a culture of entrepreneurship.

- Yet, in some countries, institutional constraints – such as employment rules for civil servants and bans on creating private organizations at public universities (or joint-ventures with firms) limit academic entrepreneurship and the potential exploitation of patents and other forms of IP.

- University patenting is growing in emerging countries. By 2010, there were about 759 PCT filings from universities in middle-income countries, whereas the total number of filings reported by PROs was 500. However, about half of the expansion in university patenting in middle-income countries are from Chinese universities. The distribution is even more concentrated with regards to patents owned by PROs in middle-income countries.

- Patenting by scientific institutions in middle-income countries mirrors technology trends in high-income countries. Biotechnology, pharmaceuticals, measurement technologies and organic fine chemistry are the main technology areas in PCT patent filings by these advanced economies and middle-income countries, such as Brazil, China, South Africa and India.

- University capacity to patent and the infrastructure for technology transfer differ widely across and within middle-income countries analyzed. Within each country studied, the bulk of patenting and technology transfer is concentrated in very few institutions, and often, in specific regions.

- In general, technology commercialization is at the embryonic stage. According to the interviews conducted, the three most important factors affecting patenting as considered by TTO managers are: i) (limited) awareness of the benefits of IP among researchers, ii) (weak) linkages with industry, and iii) having inventions with good commercial potential. Interviewees agree that relationships with firms are yet to be developed and/or strengthened.

The challenges faced to take advantage of patenting as instrument for technology transfer in middle- and low-income countries:

- Provide an enabling environment. Complementary factors needed for developing an efficient technology transfer system are currently being built and with few exceptions, they are mostly at initial stages. In many middle- and low-income countries reaching a critical mass of research is yet to be done.

- Need to leverage research with innovative potential by striking a better balance between applied and basic research; improve industry-science communication; increase autonomy of institutions, decentralizing recruiting, provide performance based incentives and acknowledge technology transfer activities in researchers' career.

- Adopting appropriate IP policies with specific definition of responsibilities, tasks and incentives. IP policies should be part of the universities' technology objectives.

- Commitment for building solid and effective TTOs. With a few exceptions, most TTOs encounter several difficulties: they are under-resourced, struggle to get funded both internally and externally, and lack skilled personal and infrastructure. They also face a high turnover, do not have staff with industry experience and only a few of them benefit from revenue sharing.

- Universities and PROs do not have operative guidelines about disclosure and patenting, and there is limited awareness by researchers of the new policy frameworks and benefits derived from IP activities. Few TTOs conduct patentability assessments (market and technical evaluation of technologies) either internally or externally.

- These weaknesses call for public action in order to harness the whole potential and opportunities offered by new policy frameworks and the use of IP in technology transfer.

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Introduction

Research institutions and universities around the world have become more aware of the opportunities offered by intellectual property (IP) for commercialization of research results, and as a tool for attracting capital, contract research, and greater cross-fertilization between entrepreneurial faculty and industry, among other potential benefits (OECD, 2003). Technology transfer policies have multiplied worldwide with special emphasis on the role of science in the creation of high technology industries, and formation of regional and national competitive advantages. Patents are expected to play a strategic role in the development of new technological competences, primarily through licensing of scientific inventions and the creation of high-technology based firms. By granting universities and public research organizations (PROs) the rights to their own intellectual property (IP) - patents, copyrights, trademarks, utility models, industrial designs - derived from state-financed research, and allowing them to commercialize their results, governments seek to accelerate the transformation of scientific discoveries into industrial applications, and to strengthen collaborative ties with industries.

This motivation drives similar initiatives in middle- and low-income countries. Through a variety of policies and national strategies, many universities and PROs in middle- and low-income countries are creating IP and the technology transfer offices (TTOs) to enhance industry-science linkages and promote commercialization of technology. The strengthening and broadening of IP rights during the mid-1990s and early 2000s, made IP frameworks similar to high-income countries and expanded opportunities for patenting. New policy frameworks for innovation are being adopted, including the provision of IP rights to research institutions, reforms to the governance of higher education systems, and the creation of technology transfer infrastructure (incubation, technology funds and venture capital). Other policy mechanisms include: the creation of coordinating agencies for IP valorization and commercialization, the development of science and technology parks, the creation of institutional incentives to facilitate patenting, and incentives for collaborative research and development (R&D) such as matching grants and consortia, among others.

This evolution has led to numerous questions, notably, the applicability of such policy frameworks to developing country contexts. What are the main strengths and weaknesses in such policy frameworks? How can patenting at scientific institutions facilitate economic catching-up? What instruments are employed? What are the context conditions required to improve technology transfer in developing countries and what role do patents play in this process? Which technologies are being patented? As patents may have unintended negative effects, how should such policy strategies be conceived in order to maximize their economic and social impact?

This investigation presents an assessment of the current state of IP policies and patenting practices in middle- and low-income countries. Acknowledging the important structural differences between high-, middle- and low-income countries, both in terms of research and education systems, as well as in terms of development concerns, this report discusses the possibilities offered by such policy initiatives, and analyzes under what conditions IP solutions are applicable. We focus on academic patenting.

This document is organized in six chapters. Section I describes the economic fundamentals underlying scientific patenting and discusses current conditions for technology transfer in developing countries. Section II presents a survey of regulatory frameworks governing university and public sector technology transfer in a group of middle- and low-income countries. Section III uncovers the state of patenting by universities and PROs, and investigates differences between middle-income and high-income countries. Section IV presents an assessment of current patenting practices and technology commercialization in a group of universities. Based on interviews conducted with 10 technology transfer office (TTO) managers, we identify obstacles encountered in patenting and technology commercialization, as well as elements of success. The final section discusses policy implications of patenting inventions from scientific research and presents policy recommendations.

I. PATENTING AT GOVERNMENT-FUNDED RESEARCH INSTITUTIONS

1.1 The promotion of patenting and technology transfer

Universities and PROs are essential to the economic development of countries. They are the main source of fundamental knowledge leading to new technology developments and economic advantages. Science has consistently been proven to be a fundamental driver of technological progress and economic growth, and a source of innovation to the business sector (Jaffe, 1989; Adams, 1990; Cohen *et al,* 2002a).[1] Its importance for economic progress has increased as recent changes in the international economic environment have increased the role of knowledge as a driver of competitiveness, and new technologies have opened up new opportunities for development. In this context, research institutions are increasingly required to amplify their impact on the economy and society.

1.2 Policy motivations

The rationale for patenting by research institutions is based on the idea that open science is not sufficient to impact industry and generate industrial innovation. The economic justification for university patenting is to facilitate the exploitation of scientific discoveries by industry through the provision of proprietary rights over inventions (Montobbio, 2009).[2] Typically, inventions developed by universities are often embryonic and need further investment for development (Jensen and Thursby, 2001; Colyvas *et al,* 2002).[3] Accordingly, firms would be reluctant to invest if inventions could be appropriated by third parties who would diminish the expected gains.[4] Such investment involves high risk, since neither the practicality of the inventions nor their market utility have been proven.

Patents can facilitate technology commercialization by reducing the legal uncertainty surrounding the protection of inventions and informing about commercial potential of technology (Teece, 1982; Arora *et al,* 2001). Although the relevance of patents as mechanisms of protection against imitation differs across technologies and industries (e.g. Levin *et al,* 1987; Cohen *et al,* 2002b), there is evidence that illustrates their usefulness in facilitating technology transfer from science (e.g. Colyvas *et al*. 2002; Nerkar and Shane, 2003). In particular, patents have been key factors in the commercialization of nascent and radical technologies at American universities. Case studies on inventions licensed by Columbia and Stanford by Colyvas *et al*. (2002) suggest that patents and exclusivity (in patent licensing) are among the most important factors to ensure industrial development of embryonic inventions in the fields of biotechnology, biological processes, medical devices and software programs. There is well-documented evidence in the case of the biotechnology industry, notably from the Massachusetts Institute of Technology (MIT) and Stanford, that IP has been a key element in the organization of the technology transfer process especially for new companies (Nelsen, 2007). Furthermore, the evidence also shows that patents help academic start-up firms to survive by facilitating the firms' access to technology markets and finance (venture

[1] Business surveys such as the 1983 Yale Survey and the 1994 Carnegie Mellon Survey (CMS) have shown the high importance of university research as source of knowledge for industrial innovation (Cohen et al., 2002a).

[2] The legal protection conferred by a patent gives its owner the right to exclude others from making, using, selling, offering for sale or importing the patented invention for the term of the patent, which is usually 20 years from the filing date, and in the country or countries concerned by the protection (OECD, 2009a).

[3] Based on a survey of 62 universities, Jensen and Thursby (2001) show that over 75% of the licensed inventions were at the proof of concept stage and only 12 percent were ready for commercial use.

[4] In principle, this argument would require patenting licensing to be exclusive in order to provide sufficient incentives for firms to incur the additional costs of developing inventions; such restriction however is not always mandatory. Important crosscutting technologies have been successfully diffused through non-exclusive licensing, for instance the licensing of the Cohen-Boyer patent at Stanford (Feldman *et al*, 2007).

capital) (Nerkar and Shane, 2003; Darcy *et al,* 2009; Zuniga and Guellec, 2009).[5]

From a public policy perspective, patenting and licensing of scientific inventions is motivated by a desire to increase economic impact of public research through the creation of formal links between science and industry. Evidence provided by Zucker *et al,* (1998) and Zucker and Darby (2001), demonstrates the importance of science linkages in start-up creation, new product development and the development of high-technology districts (e.g. biotechnology and nanotechnology in the United States and Japan).

There is an additional policy interest in ensuring protection of inventions at publicly funded research institutions. Universities and PROs are motivated by the need to preserve the "public good" nature of knowledge. In technology areas with high social impact like pharmaceuticals and agriculture, importance is placed on protecting research results, not only for purposes of commercialization, but to avoid patenting by others, and maintain and control of research results and ensuring freedom to operate (e.g. Wolson, 2007a; 2007b). The use of patenting at research institutions requires careful design. As explained by Montobbio (2009), two aspects of intellectual property must be considered: protection for private commercialization purposes and protection of public interests. The latter means the adoption of specific policies that look after the adequate dissemination of technologies in coherence with regional economic and social needs. For instance, non-exclusivity licensing and preferential licenses (e.g. small and local firms) have been advanced as appropriate strategies to be explored in developing country context (So *et al,* 2008; Sampat, 2009a; 2009b).

It is important to bear in mind that not all innovations are patentable and not all patents have an economic and technical value (Griliches, 1991, OECD; 2009a). Furthermore, not all technologies from scientific research need to be patented in order to reach the markets (So *et al,* 2008). Experience has shown that patenting plays a major role for technology commercialization in scientific areas where there is a narrow border between science and markets. In fact, most university patenting worldwide is centered in biotechnology and biomedical sciences, where scientific discoveries have an immediate application in that industry (Mowery *et al,* 2002; Mowery and Sampat, 2005).

1.3 The use of patents: benefits and undesired effects

1.3.1 Potential benefits

Technology commercialization at universities can have important economic benefits for society and for universities themselves. It is often argued that university technology transactions can generate important economic and technological spillovers through the stimulation of additional R&D investment and job creation (Rosenberg and Nelson, 1994; Siegel *et al.,* 2007).[6] Patent licensing agreements and university based start-ups can result in new sources of employment opportunities for students and young researchers. Furthermore, research has shown that university patenting and licensing have been fundamental to the emergence of new industries such as the scientific instruments industry, semiconductors, computer software, and biotechnology industries (Rosenberg and Nelson, 1994).

Empirical evidence provided by Zucker and Darby (1996), and Zucker *et al* (1998), among others, has

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[5] Nerkar and Shane (2003) report evidence of the survival capabilities of academic start-ups based on an empirical analysis of 128 firms owned by the MIT between 1980 and 1996. Accordingly, technology radicalness and patent scope of inventions are associated to less likelihood of firm failure in fragmented industries.

[6] According to the Association of University Technology Managers (2001), spinoffs from American academic institutions between 1980 and 1999 have contributed to 280 000 jobs to the US economy and $33.5 billion in economic value added activity (O'Shea *et al.,* 2008; Shane 2004).

shown the importance of scientific linkages (notably the role of star scientists) in the creation of start-ups in the fields of biotechnology and nanotechnology in the United States and Japan.

The evidence regarding the impact in terms of employment is however limited. Vincett (2010) reports evidence for Canada that academic spin-offs represent substantial contributions to gross domestic product (GDP), much larger (on a time discounted basis) than their implied costs (government funding).[7] For United States (US) universities, Shane (2004) finds evidence that spinoff companies from universities are 108 times more likely than the average new firm to go public and also to create more jobs than the average new business in the US. However, much of this activity is highly concentrated in life sciences. Furthermore, there is substantial firm heterogeneity in the use of industrial scientific links for innovation; not all firms are able to use complex fundamental knowledge and there are important industry effects (Belderbos *et al.,* 2004).

We should notice that there is rich evidence on the innovation effects stemming from industry-science research collaboration. Numerous studies confirm the existence of complementary effects between R&D cooperation and firm innovation activities. As explained by Cassiman *et al* (2007) and Bishop *et al* (2010), firms gain multiple benefits from collaboration with universities in activities that range from basic research and developing know-how to assistance with market introduction. Benefits for firms include an increase in the level of applied research effort (Evenson and Kislev, 1976), overall R&D productivity as measured by patents ("more important patents": Henderson and Cockburn, 1994; higher quality of patents: Zucker and Darby, 2001), introduction of new products (Cockburn and Henderson, 1998), and labor cost reductions (Stern, 1999), among other benefits. The empirical literature has also shown a positive impact of scientific connections, notably research partnerships with universities on firm's R&D investment (Adams *et al,* 2000), innovation productivity and sales (Audretsch and Stephan, 1996; Cockburn and Henderson, 1998; Zucker *et al,* 1998).

Linkages with industry can have enriching effects for university research as well (Agrawal and Henderson, 2002; Breschi *et al.,* 2007), although there is an important heterogeneity in the forms and intensity of science-industry linkages among research disciplines (Montobbio, 2009; Gulbrandsen *et al.,* 2011). Recent studies suggest that industry-science collaborations can lead to research complementarities and might even trigger new basic research. Interactions can lead to the realization of synergies between applied and basic research (Azoulay *et al.,* 2006) and new research ideas (Rosenberg, 1998). Owen-Smith and Powell (2003) explain that universities connectivity with industries help researchers to identify more promising research venues for technological development.[8] Reaping the benefits of such connections, however, requires experience in balancing academic and corporate priorities to avoid the risk of 'capture' by industrial interests as overly-tight connections can lead to research that is too practical and with limited technological contribution (ibid). There is additional evidence showing that linkages with industry help scientific institutions to deal with the problem of underfunding of research (Agrawal and Henderson, 2002; Czanitzki *et al.,* 2010; Thursby and Thursby, 2011). Revenues from patent licensing however are often confined to very few inventions in university patent portfolios.

1.3.2 Potential Drawbacks

[7] Accordingly, lifetime impacts of university spinoffs created in 1996-1998 exceeded government funding received (direct and indirect) over the same period by a substantial margins. The author also states that governments also benefit from additional tax from new firms.

[8] Owen-Smith and Powell (2003) explain that technology licensing officers can draw upon the expertise of corporate partners to evaluate the potential impact of invention disclosures. As a result, well connected universities are able to develop high impact patent portfolios. They draw upon quantitative data for a panel of 89 research-intensive U.S. universities in the field of life sciences and interview data from two academic licensing offices.

Patenting is not an end in itself, but rather an instrument to facilitate technology transfer from scientific institutions to industry. The use of patents at scientific institutions is not without drawbacks and therefore the design of patenting policies at research institutions requires due diligence and the inclusion of policy safeguards to minimize unintended effects. Undesirable effects could arise from indiscriminate patenting such as patenting overly broad inventions and patenting platform technologies and research tools, which in turn can hinder scientific research. It has been stressed that increased commercialization of technology may alter scientific norms due to disclosure restrictions (and restrictions regarding access to materials and data), changes in the nature of the research (shifting interests from basic research to commercial research), diverting energies from teaching activity and even making relationships with industry more difficult (Baldini, 2008; Foray and Lissoni, 2010).

The literature tends to suggest that fundamental research is unaffected by patent and patent licensing activities. Most of the evidence refers to high-income countries, especially United States, and is largely focused on life sciences. The study by Rafferty (2007) shows no effect of the Bayh Dole Act on the ratio of applied versus basic research at universities. He actually finds that changes in research at universities did indeed occur, but they took place well before the passage of the Act. Henderson *et al.,* (1998) report that both the importance (number of patent citations received) and generality (intensity of being cited across a wide range of fields) of university patents declined compared to other patents during the 1980s.[9] Studies by Mowery *et al.,* (2002) and Sampat *et al.,* (2003), show however, that such a decline is explained by the entry of new universities into patenting (illustrating a learning process) which tends to be slow at first, but catch-up over time. Controlling for this, and other inter temporal effects, confirms that there has been no aggregate decline in patent quality.

With respect to the impact of patenting on publication, there is weak evidence of a crowding out effect. According to recent survey studies, getting involved in patent and licensing activities is not incompatible with researchers' interests. Researchers may use patenting and patent licensing as instruments for career advancement. They would take advantage of new funding mechanisms and linkages with industry to gather additional sources of funding to continue personal research agendas while maximizing industry impact from fundamental research. Evidence on this rationale is reported by Thursby and Thursby (2011). In a study of 11 major US universities over a period of 17 years, they find evidence that recent (and repeated) disclosure activity is associated with publication count as well as the importance of these publications in terms of citations. Indeed, motivations to engage in technology transfer activities go beyond purely financial reasons (Baldini, 2010). Reputation and peer recognition motivate participation in technology transfer activities as well as the need to access additional funding and identify new research ideas through industry interaction. In general, scientists that patent tend to publish more (e.g. Louis *et al.,* 1989; Agrawal and Henderson, 2002; Van Looy *et al.,* 2004), and vice versa (e.g. Stephan *et al* 2007; Azoulay *et al.,* 2006); and universities that patent more are those that publish the most as well (Carayol and Matt, 2004; Blumenthal *et al.,* 1996).

Substitute effects between patenting and publication may arise but they are only valid under specific circumstances, notably when researchers have already achieved a prominent scientific career and researchers who have patented a lot (Fabrizio and Di Minin, 2008; Gulbrandsen *et al.,* 2011; Crespi *et al.,* 2010). Evidence on substitution effects between publishing and patenting has been reported though when academics participate in corporate patents as inventors (e.g. see Czarnitzki *et al.,* 2010; on German academic inventors). Yet the importance of patenting varies across scientific disciplines and motivations related to patenting also differ across scientists and areas of research (Montobbio, 2009; Sauerman *et al.,*

[9] Using a different methodological approach, Rosell and Agrawal (2009) find similar conclusions when comparing 1980-1983 versus 1990-1993 for the measure of originality and 1980-1983 versus 1986-1989 for the indicator of generality).

2010).[10] An additional preoccupation is the impact that (tighter) management of IP and university commercial interests may have on industry collaboration. Valentin and Jensen (2007) observed a decline in collaboration between Danish firms and Danish scientists - following the introduction of the Law on University Patenting. This trend suggests that the new policy framework may have hindered traditional forms of interaction.

And last but not least, a fundamental concern is that patents may hamper the progress of research by means of blocking access to technologies. First, if platform technologies and too broad inventions are patented, there can be situations where research (and commercialization) gets blocked ('the anti commons').[11] There is evidence that such a risk exists, but its effects are rather weak (e.g. Murray and Stern, 2007; Walsh *et al.,* 2003; Walsh *et al.,* 2007). Furthermore, most studies have focused on biomedical technologies where applied and basic research overlap and hold-up situations are more likely. Little evidence exists for other technology areas. For instance, Murray and Stern (2007), in a study of patent-paper pairs in biology sciences (and a control group of publications for which no patent was granted), find that citations in science received by publications having associated patents decline by between 9% and 17% after the patent grant. Sampat (2006) finds that university patents are increasingly containing scientific references (compared to a control group), suggesting that universities are increasingly patenting science rather than technological results derived from research. In contrast, Walsh *et al.*, (2003), in a survey before business representatives and scientists, found that property rights seldom prevented the pursuit of "worthwhile" projects. Further, Walsh *et al.,* (2007), on the basis of survey responses from 507 academic biomedical researchers, observed that access to knowledge inputs is largely unaffected by patents. However, accessing other researchers' materials and/or data, such as cell lines, reagents, or unpublished information is found more problematic and associated to many other factors.[12] The weak effects found in biotech and life sciences may be partially explained by the use of policy safeguards and alternative approaches to the management of IP.

To ensure fluidity and technology exchanges within scientific communities, research institutions worldwide are using open innovation models through which IP is pooled for collective access, such as creative commons for databases and copyrights, patent funds and patent clearing house.[13] Furthermore, a major lesson from the US experience is the need of adopting research exemptions to avoid unintended hindrances in the use of (patented) research tools, materials and data for purposes of scientific research. In 2004, the European Commission published a report on the management of IP in research institutions that recommended such approaches in technology transfer practices. Codes of practices in patent

[10] For instance, in a recent survey study on American researchers, Sauerman *et al* (2010) find that the desire to contribute to society is the key motive predicting patenting in the life sciences, while pecuniary motives are predictors of patenting in the physical sciences. In engineering, challenge and advancement are what matters.

[11] The "anti commons' effect, a term conceived by Heller and Eisenberg (1998) refers to the situation where innovation is constrained by the transactions costs derived from the multiplicity of technologies (and multiple parties owning such innovations) needed as inputs for its development. Proprietary technologies may be underutilized as a result, which in turn, constrains and delays further innovation.

[12] Accordingly, restricted access to materials and/or data is motivated by scientific competition, the cost of materials, a history of commercial activity on the part of the prospective supplier, and whether the material in question is itself a drug (ibid).

[13] There are several interesting examples of open-innovation practices (e.g. commons for databases and copyrights, patent funds and patent clearing houses) in the areas of health and agriculture. An example is the Biological Innovation for Open Society (BIOS) initiative—recently launched by CAMBIA, a non-profit research institute in Australia—which aims to create a common pool of technologies in biotechnology that are made freely available to scientists who could otherwise not afford them (Michiels and Koo, 2008). The Equitable Access License (from UAEM: Universities Allied for Essential Medicines) for health innovations and PIPRA's (Public Intellectual Property Resource for Agriculture) use reservation of rights for agriculture are two examples (Boettiger and Benett, 2006). In response to concerns about IP impediments to R&D in subsistence crops for the developing world, PIPRA created a mechanism for its members to collaboratively manage their agricultural IP under a concept of "publicly minded licensing".

licensing are also spreading, either through national guidelines or created by institutions themselves,, and are aimed at preventing abusive patenting and licensing (OECD, 2003; Montobbio, 2009; Sampat, 2009b).

Box 1: Implications of university patenting on research by developing countries

The empirical evaluation of the impact of academic patenting on research and innovation in developing countries is scarce. There are a few analyses pointing to a notorious change in research portfolios and growing university patenting activity worldwide (Michiels and Koo, 2008; Sampat, 2009b). There are indications that research and patenting in biotechnology in middle- and low-income countries show patterns similar to those in high-income countries. According to the analysis of Michiels and Koo (2008), the research focus in plant transformation technology has shifted from fundamental to applied research, and has been accompanied by growing patenting activity: while the majority of the published journal papers (nearly 73%) were of a fundamental nature in 1996, only 21% of papers published in 2004 discussed fundamental research problems.[14] They also noticed that the distribution of patent ownership has also evolved towards a greater participation by universities in patenting. A rapid rise of middle-income countries (especially China and India) is identified in applied research in crop improvement (their share in published articles increased from 5 percent in 1996 to 17 percent in 2004), which suggests a worldwide movement toward applied technologies in this field.

It has also been stressed that university patenting in the North can influence access to life saving innovation in middle- and low-income countries. No impact evaluation however is available discerning such effects (e.g. prices of drugs and consumption). Sampat (2009b) 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 universities or firms licensing university technologies would have to file patents in developing countries. Sampat gathered data and found evidence for these two conditions, and notably a high presence of academic patents in drugs related to HIV/AIDS (25% of key drugs).[15] Accordingly, these findings stress the possibility for universities to play a strategic role in promoting access to drugs in developing countries.

It has also been argued that the strengthening of patents worldwide may shift research interests in high-income countries towards projects with relevance to markets in developing countries (e.g. see Diwan and Rodrick, 1991).[16] In this respect, there is no evidence available that have looked at the impact of university patenting on research agendas. The only related study is the one by Lanjouw and Cockburn (2000). They have empirically examined the impact of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) on patenting activity on diseases relevant to the developing world. Accordingly, the share of research in these areas in total scientific publication activity showed no major change in terms of share in total patenting, with the exception of malaria research where a minor increase has been noted.[17] According to the US National Institutes of Health, a similar trend is observed for

[14] The authors argue that the increased patentability of research outputs has been influenced by changes in patent regimes and the growth of commercial markets for crop varieties might have encouraged the shift of research focus.

[15] He gathered data on these two trends and found that universities own patents on nearly 1 in 5 (19.2%) of the drugs that are arguably the most innovative and 1 in 4 of the HIV/AIDS drugs, which is particularly important for the developing world. He also found that universities, and the firms that commercialize and market drugs with academic patents, currently apply for patents in developing countries. For patents filed after 1995, at least 44% of academic patents, and 62% of firms' patents on drugs with academic patents, were filed in developing countries.

[16] It could also possibly happen that, bureaucracy in registration and commercialization could take unreasonable amount of time for researchers and drive scientists away from reporting or even engaging in industrial research.

[17] With much effort, a 10 to 15% increase in the number of patents on neglected diseases is discernible between

scientific articles related to tropical diseases (they represent 1.5% of the total, see Combe *et al.,* 2003). The role of university patenting is difficult to discern in these trends given the limited activity and the associated increase of funding by international organizations and public agencies, notably in HIV/AIDs and malaria.

It has been claimed that the patenting of scientific results in high-income countries could restrict access to research tools and technologies in middle- and low-income countries (Boettiger and Benett, 2006; So *et al.,* 2008; Montobio, 2009), and in turn affect research and access to knowledge in developing countries. It has further been argued that such a situation could be considerably harmful in countries where research systems are still developing (Engel, 2008). In particular, there have been fears that stricter IP practices may hinder access to technologies in areas where knowledge has traditionally been treated as public good for developing countries (e.g. agriculture and health). There is no empirical evidence insofar, however, about such impacts. As previously emphasized, to avoid undesired research blocking situations, open-innovation practices are also spreading in north-south (and south-south) research collaboration. Box 1 summarizes some of these concerns and discusses recent studies field. It is clear that further research is needed to really understand what the repercussions are on developing countries' research activities and access to technologies.

1.4 Knowledge Transfer Channels

The international experience suggests that care should be taken when promoting university patenting to avoid negative repercussions on traditional forms of knowledge transfer. The ways in which knowledge is transferred from scientific institutions to industry are diverse. Industry receives new ideas from science through informal means, including publications and conferences, informal contacts, as well as through formalized channels such as the hiring of new graduates and post-graduates, (sharing of) equipment and instrumentation, contracting technology services, research collaboration, licensing of prototypes for new products and processes, licensing of know-how, and firm creation. Informal channels are particularly important to firms in middle- and low-income countries.

Survey evidence from Brazil (Rapini *et al,* 2006; Costa Povoa and Rapini, 2010), Argentina (Arza and Vazquez, 2010), Costa Rica (Orozco and Ruiz, 2010), Mexico (Dutrenit *et al,* 2010), Thailand (Intarakumnerd *et al*, 2002) displays striking similarities with US and European evidence (Cohen *et al,* 2002a; Bekkers and Bodas Freitas, 2008). As opposed to formal links, R&D collaboration, R&D contracting, personal mobility, patent licensing and spinoffs, informal links such as personal contacts, publications, information disseminated at meeting and conferences are the most frequent channels through which knowledge diffuses to firms.[18] In addition, the provision of technology services ranks also high in middle-income countries for which survey information is available. In general, the studies above mentioned also show that "commercial" channels of knowledge transfer (patents, patent licensing, spinoffs) rank lower in the scale of importance.

Evidence from Argentinean researchers shows that consultancy, informal information exchange and conferences are the most valued forms of interaction, with, respectively, 79%, 45% and 44% of respondents considering those forms, as at least, moderately important (Arza and Vazquez, 2010). Co-

1985 and 1990. Yet, the number of granted patents on tropical diseases remains very marginal (0.5% of the pharmaceutical patents).

[18] The relative importance of such channels differs according to the particular scientific field, the stage of development of technology, and across regions because technology transfer mechanisms are influenced by the country's institutional settings and research systems (Montobbio, 2009).

operative R&D and research contracts, training staff, recently hired graduates and publications follow in importance with similar scores in the range of 25-40% and finally, less than 10% of researchers considered patents, science parks and spinoffs as moderately important channels. In a similar study on Brazilian researchers, Costa Povoa and Rapini (2010) found that the main channels used by researchers who declared being involved in some kind of technology transfer were: publications and reports (74%), conversations (45.4%), training (44%) and consulting (42%). Only 14% of respondents pointed to the use of patents to transfer technology. It is true though that patenting and commercialization are, in most cases, very recent in middle- and low-income countries, and therefore comparisons across channels in these studies should be put in context.[19]

1.5 Research systems in middle- and low-income countries

As providers of human capital and diffusers of new ideas and organizational modes, scientific institutions are an important part of the institutional structure needed for economic development (Mazzoleni and Nelson, 2007). In developing countries, especially in lower-middle- and low-income countries, PROs and universities are key institutions supporting the process of economic catching up, not only through research but mostly through the formation of human capital, training, and assistance to firms in technology upgrading and absorption (Mazzoleni and Nelson, 2007; Link and Scott, 2004; Yawson, 2002; Yawson *et al,* 2006). These aspects should be taken into account when defining technology transfer goals and the type of entrepreneurial activities that research institutions should undertake.

The international experience shows that the role of universities in national innovation systems evolves with the level of economic development (Arocena and Stutz, 2001; Mazzoleni and Nelson, 2007; Engel, 2008). During the early stages of development, provision of human capital and industry training are the most important tasks of universities in the pursuit of economic development (Mazzoleni and Nelson, 2007). As countries develop and technological needs begin to mirror those of high-income countries, research becomes more innovative and incentives for innovation protection increase.[20] Scientific knowledge becomes more relevant then for firms to develop new technological advantages. These aspects should be taken into account when considering the use of patenting to enhance the economic impact of universities and research institutions.

PROs

Research systems in middle- and low-income countries differ in different dimensions with respect to their peers in advanced countries. In most developing countries, the bulk of research activities have traditionally been concentrated in PROs (UNESCO, 2009).[21] Figure 1 and 2 illustrate the high weight that governmental institutions have in R&D activities, in both funding and performance.

Many middle- and low-income countries have research institutes in key national areas. Some of them have research centers and technology institutes with international standards, with state of the art

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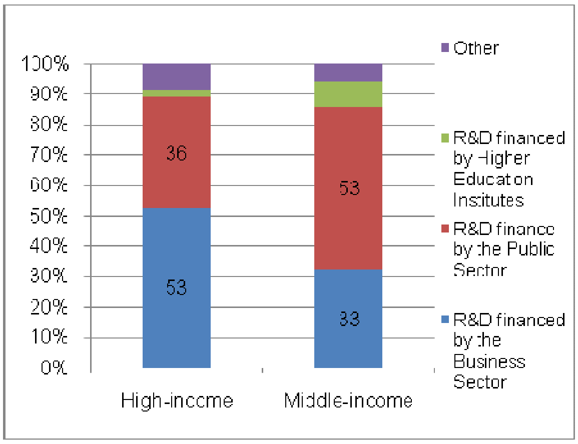
[19] As in Cohen *et al,* (2002a), it is also found for Brazil (Rapini *et al*, 2006), that engineering and applied sciences are the fields wherein most of the fruitful university-industry interactions have formed and that such knowledge transfer only rarely consists of embryonic product concepts and prototypes. These findings stress the sector-effect in industry-science linkages. They also highlight the importance of considering the diversity of knowledge flows in the promotion of technology transfer policies.

[20] As evidenced by many studies (e.g. Maskus, 2000), patent protection has a nonlinear relationship with economic development: technology diffusion (and weak protection) predominates at earlier stages, and protection increases as innovation capabilities emerge.[20] These aspects should be taken into account when determining a country's strategy for technology transfer, and the role that university patenting may play in such processes.

[21] For a review of country research systems, see UNESCO (2009).

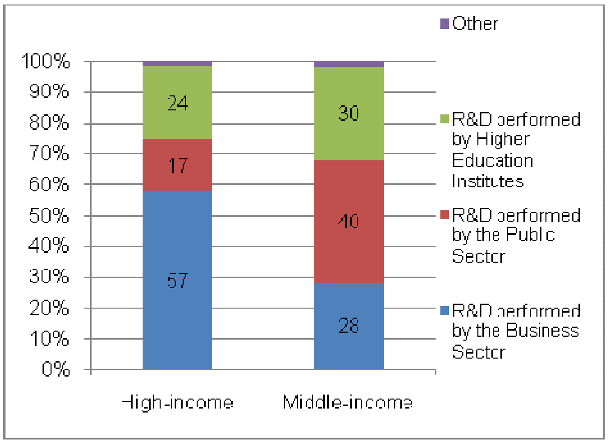
infrastructure and are at the frontier of science in several fields. However, in most cases, research from national laboratories has not played a substantial role in the process of technological catch up, beyond providing training and basic technological services, for example calibration, quality testing and norms, and assistance in technology upgrading and absorption (Mazzoleni and Nelson, 2007). Even at the largest PROs in middle-income countries, (i.e. Mexico, Brazil, China, Russian Federation or Malaysia), IP has been absent in technology transfer policies (Ram, 2008; Solleiro and Escalante, 2009; Sibanda, 2009). The interaction of PROs with the economy has been limited to strategic sectors (e.g. agriculture and energy) and with state firms for a while. In general, most research institutes have worked on isolation and only a few have acted as knowledge bridging organizations (Mazzoleni and Nelson, 2007). This situation has started to change in emerging economies in the last decade.

Figure 1: National R&D by sources of funding 2007 (or latest year)



Source: UNESCO Statistics (November 2010).
Note: Statistics for Low-income countries are not available (only four countries report data).[22]

Figure 2: National R&D by sector of performance 2007 (or latest year)



Source: UNESCO Statistics (November 2010).
Note: Statistics for Low-income countries are not available (only four countries report data).[23]

As explained by Intarakumnerd *et al,* (2002) for Thailand, Dutrenit *et al,* (2008) for Mexico, and Mazzoleni and Nelson (2007), linkages between PROs and the business sector are constrained by a number of structural factors and inertias. Insufficient R&D infrastructure and the lack of research agendas applicable to the private sector have limited the development of science-industry linkages.

Additionally, the scant interaction with industry is also explained by the direction of research. In many

[22] Middle-income: Guatemala, Paraguay (2005), Slovenia, Philippines (2005), Ecuador, Azerbaijan, Sri Lanka (2006), Mongolia, Thailand (2005), Morocco (2006), Pakistan, India, Ukraine, Tunisia (2005), China, Cuba, Colombia, Kazakhstan, Mauritius (2005), Mexico, Uruguay, Bulgaria, Argentina, Poland, Latvia, Malaysia (2006)m Turkey, Lithuania, Belarus, Montenegro, Brazil, and Russian Federation.

[23] Statistics for Low-income countries are not available (only six countries report data). High-income: Kuwait, Trinidad and Tobago, Cyprus, Malta, Croatia, Estonia, Slovenia, Singapore, Israel, Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, German, Hungary, Iceland, Ireland, Italy, Japan, Korea (Rep.), Luxembourg, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom, United States. Middle-income: Indonesia (2005), Georgia (2005), Sudan (2005), Guatemala, Paraguay (2005), Slovenia, Philippines (2005), Ecuador, Azerbaijan, Sri Lanka (2006), Mongolia, Thailand (2005), Morocco (2006), Pakistan, India, Ukraine, Tunisia (2005), China, Colombia, Kazakhstan, Seychelles (2005), Costa Rica, Serbia, Bosnia and Herzegovina, Mexico, Bulgaria, Argentina, Poland, Latvia, Malaysia (2006), Botswana (2005), Turkey, Lithuania, Belarus, Montenegro, Brazil, and Russian Federation.

countries, federally funded science and technology (S&T) expenditure has largely focused on agriculture and overlooked engineering and industrial research in many developing countries (Mazzzoleni and Nelson, 2007; Intarakumnerd *et al,* 2002). The lack of applied research, the deficit of trained engineers and applied scientists, and the weak attention given to the development of technological capabilities for the manufacturing sector are all factors that contribute to the disconnection between science and firms. In sector-specific research organizations, governance and regulation is directed by the appropriate Ministries (agriculture, fishing, energy, water or health) and focused mainly on technical support to public sector institutions. Historically, interaction with the private sector was absent, and in some cases, highly regulated according to the Ministerial bylaws. Nowadays, many PROs and technological institutes face the challenges presented by having an aging staff and retaining young qualified staff. This is the case in countries such as Chile (World Bank, 2009) and Kenya (Flaherty *et al,* 2010).

However, there are several examples of PROs making key contributions to the development of strategic economic sectors. The experiences of Republic of Korea (in the 1970s and 80s), Brazil, Malaysia and Singapore (in the 1980s) demonstrate that PROs and universities can play a critical role in industry development (in electronics in Republic of Korea; in the aircraft and agricultural industry in Brazil). Despite their limitations, PROs can perform the role of coordinator or “fixers” of systemic failures in innovation systems (Intarakumnerd *et al,* 2002). According to Mazzoleni and Nelson (2007), successful models of public research involvement in the development of industries all share distinctive features: they respond to specific industry needs (and work hand with hand); they have a well defined user community (or industry), and they have predominantly occurred in areas of applied sciences and engineering where research has been oriented towards problem-solving and tailoring technologies to local conditions.

There are examples of these positive effects in large, emerging economies as well as less developed economies. Institutions such as the *Hong Kong Productivity Centre* and the *Korean Institute of Science and Technology* provided institutional and technical supports for industrial development within firms. They successfully engaged in technical assistance and contributed to strengthening the absorptive capability of local firms through training, quality testing and product development, linking with multinationals, organized R&D consortium and spin-offs. Latin America provides some interesting cases of PROs in agricultural research. In Argentina, the INTA, th*e National Institute of Agricultural Technology,* which is the country’s major government agricultural R&D institution, integrates research and extension services, making it unique among S&T institutions. In Brazil, the role of the *Empresa Brasileira de Pesquisa Agropecuária* (EMBRAPA), *Brazilian Agricultural Research Corporation* a semi-autonomous federal agency administered by the Ministry of Agriculture and Food Supply, is noteworthy. This institution isthe largest agricultural R&D agency in Latin America in terms of both staff numbers and expenditure, and is among the three top patentees in the country.

Universities

Research by universities is a recent activity in less developed countries. Furthermore, most of the research is concentrated in few institutions (e.g. in Latin America, 80 percent of university research is concentrated in six countries, Moreno-Brid and Ruiz-Napoles, 2007; UNESCO, 2009), and among those conducting research, technology transfer activities have largely been absent. In general terms, industry-university linkages have traditionally been weak and entrepreneurial activities are a recent isolated phenomenon.

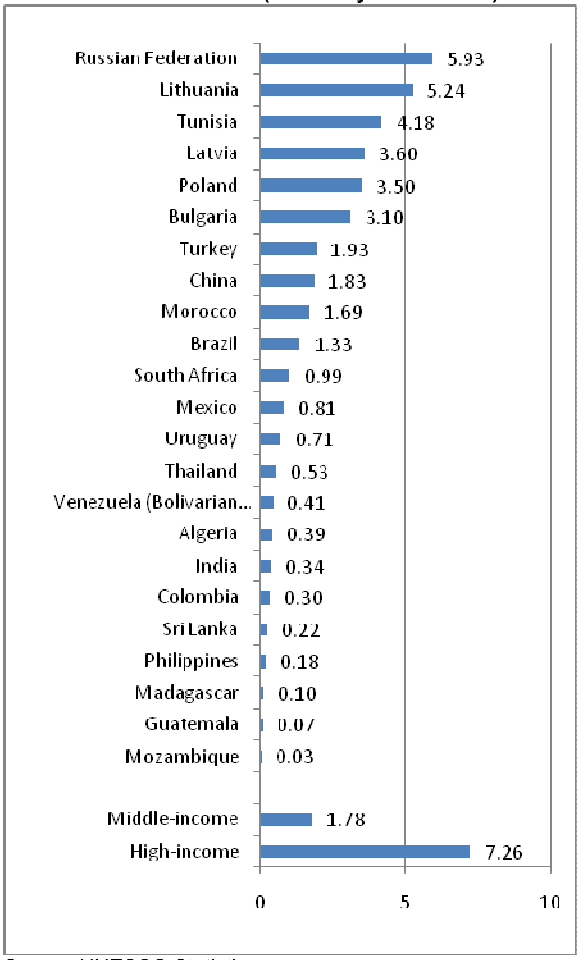
Different factors are at work here. Historically, structural features have constrained the development of industry-science ties. In many countries, commercial activities by universities and researchers have been (or still are) highly regulated or forbidden by public sector laws (e.g. Solleiro and Escalante, 2009;

Tansinsin, 2007). Autonomy has traditionally been limited, and, with few exceptions, most universities fully depend on federal budgets and have weak linkages with regional governments and economies. In some countries, recruiting of professors is managed at Ministries of Education or National Councils of Science. At those universities conducting research, the reward structure of researchers has traditionally focused on publication, which discourages researchers to get involved in technology transfer activities (SeCYT, 2003; Wolson, 2007a; Wu, 2010a, 2010b). A major element underlying universities' poor attention to technology transfer is the late emergence of public support for the development of industry-university collaboration (Kuramoto and Torero 2010; World Bank; 2010). By the mid-1990s the situation had started to change, with the adoption of national mandates for universities, calling for them to engage in technology transfer activities (the "third mission" of universities).[24]

In terms of human capital, the number of researchers at universities has been continually insufficient in many countries, hindering the development of university research capacity. Traditionally, minimal attention has been given to science, engineering, and other applied research in research agendas (i.e. see case of Latin America, Russian Federation and Republic of Korea in IADB, 2010). Graduates (and undergraduates) in science and engineering number less than those in the social sciences and humanities (Corlett and MacFarlane, 1989; IADB, 2010). Furthermore, until recently researchers have not been fully recognized as relevant factors of production in the national industries of many countries. The profession of researcher has not been presented as a rewarding and interesting career option for young people.

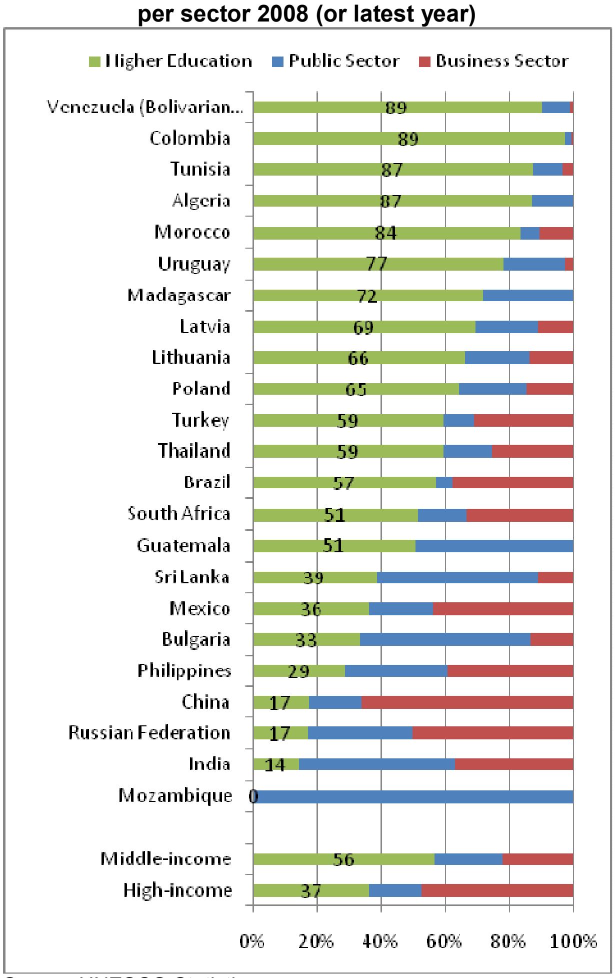
[24] In Kenya, the role of the higher education sector has grown significantly since the 1980s, and by 2008, the sector accounted for close to a quarter of the country's public agricultural R&D capacity (Flaherty *et al,* 2010).

Figure 3: Researchers (Full Time equivalent) per 1000 Labor Force 2008 (or latest year available)



Source: UNESCO Statistics.
Note: Data for OECD countries are 2008 except for Greece, Germany, Rep. of Korea France and Japan whose data are from 2007. Data for the United Kingdom and U.S. are from 2006. Algeria, Thailand, India, Philippines report data from 2005. Data for Mozambique, Tunisia, Morocco, Sri Lanka, South Africa, are 2006. Data for Guatemala, Turkey, Mexico, China and Madagascar are from 2007.

Figure 4: Researchers (Full Time equivalent) employed per sector 2008 (or latest year)



Source: UNESCO Statistics.
Note: Data for OECD countries are 2008 except for Greece, Germany, Rep. of Korea France and Japan whose data are from 2007. Data for the United Kingdom and U.S. are from 2006. Algeria, Thailand, India, Philippines report data from 2005. Data for Mozambique, Tunisia, Morocco, Sri Lanka, South Africa, are 2006. Data for Guatemala, Turkey, Mexico, China and Madagascar are from 2007.

Firms frequently complain about the inadequacy of education and research programs and their inability to match the evolving needs of industry (Intarakamnerd *et al,* 2002; World Bank, 2010). The isolation of researchers and R&D institutions has been cited as being one reason for the weak performance in building technological capabilities. The following factors have been identified as some of the constraints on research at Nigerian universities (Ogbu *et al,* 1995): poor (and outdated) research facilities; inadequate human resources; poor linkage with the production system; inadequate funds, incentives, and motivation; and lack of clear-cut enabling policies.[25] The leading factor seems to be poor funding of S&T research. Another characteristic of research systems in Africa is the limited collaboration between

[25] Other possible factors, such as socioeconomic or political factors, bureaucracy, paucity of university-based research results, and inadequate personnel, were not considered as important.

researchers and institutions (Ibid).[26] Similar conclusions are reported for Kenyan universities. The following four handicaps have been identified (Bwisa and Gacuhí, 1999): i) inadequate funding; ii) inadequate infrastructure, iii) heavy teaching loads, and iv) lack of immediate materials.

Policy frameworks have not facilitated the appropriation of benefits derived from technological commercialization at research universities in middle- and low-income countries. Many research funding agencies, retained (or still retain) ownership of IP rights from state-funded research conducted at universities. In some cases, asymmetric policies prevailed or still prevail. For instance, in Argentina the ministerial or funding-agency laws authorizing patent co-ownership between the government and inventors, while in Malaysia and South Africa, IP policies endow institutions with ownership rights over their intellectual creations (Tansinsin, 2007;Sibanda, 2009). This situation has been changing in many countries over recent years.

Funding governance

The most common funding scheme in low- and middle-income countries is the one where the federal government is the main source of financing of research. There are some variations in funding schemes though, which illustrate the heterogeneity of research systems across countries. We can roughly identify two models in addition to the traditional funding scheme. The first scheme is the one in which international donors (international aid agencies, development banks and non–governmental organizations) constitute an important source of funding for academic research, especially in health and agriculture. In Kenya, for instance, agricultural biotechnology research at large public research centers is largely donor-funded (Odame *et al,* 2011) with substantial monetary support obtained from international co-operation agencies. Donors and development banks provided 36 percent of total R&D funding at a large agriculture research organization (Kenyan Agriculture Research Institute) from 2001 to 2008 (ibid).[27] The health sector in Ghana is heavily supported by foreign funding, specifically from multilateral organizations and NGOs (Al-Bader *et al,* 2010).[28] Concerns have been expressed regarding the lack of IP strategy in the management of such collaborations and the difficulties of moving research towards technology transfer (ibid).

A different configuration prevails in a number of middle-income countries where industry funding in the form of contract research is a major source of academic research funding. This is seen in the case of South Africa (Wolson, 2007a; 2007b), Philippines (Tansinsin, 2007) and China (OECD, 2007). In South Africa, 58% of total academic research is derived from industry funding while 28% is obtained from government funds (South African S&T Indicators 2002). In the Philippines, the private sector finances 15% of R&D activities at universities (Tansinsin, 2007). These funding patterns call for special care when developing and implementing IP policies. Industry funding of academic research may represent considerable technology transfer (know-how, technical upgrading and new technological solutions), necessitating that industry trust be preserved and enhanced.

[26] Major collaborative research groups, -consisting of a lead scientist, postdoctoral fellows, and doctoral and other graduate students-, like those found in high-income countries generally do not exist in university systems in countries like Nigerian (ibid).

[27] Industry has also been important in supporting large biotechnology projects in the region (see the case of transgenic sweet potato; Odame et al, 2011).

[28] Of the 19 donors active in Ghana's health sector between 2003-2005, the largest were the World Bank (136.9 million USD), the Netherlands (103.9 million), the United Kingdom (71.4 million), the US (59.9 million) and Denmark (3.8 million). Other philanthropic agencies are also directly involved in supporting the Ministry of Health's research institutes: Rockefeller Foundation, US Agency for International Development and the National Institutes of Health (US), Meningitis Research Foundation, the Canadian International Development Research Centre and the Bill & Melinda Gates Foundation, among others (Al-Bader *et al,* 2010).

1.6 Conditions for patenting and technology transfer

To correctly understand and interpret the potential role that patents play in fostering technology commercialization in developing countries, it is necessary to look at the prevailing research capabilities and national innovation environments at large. Technological commercialization (and more broadly technology transfer) from public research and the channels through which it develops depend on several factors (OECD, 2007; World Bank, 2010), which are briefly summarized as follows (see also Box 2): ii) research capabilities and relevance, and human capital; iiii*)* the legal and regulatory framework; iiiiii) the institutional setting of research institutions (structure and governance); iviv) access to finance and intermediary structures, for example technology transfer intermediaries; and vv) firms' absorption capacity. Other factors influence the intensity and scope of linkages between universities and PROs, such as firms and society. For instance, both the economic structure and social needs of a country influence the funding and direction of research.

Box 2: Context elements that explain technology transfer

The empirical evidence for high-income countries continually demonstrates the importance of contextual elements to technology commercialization at universities. Among these are: i) the quality of research (Zucker *et al.,* 1998; Jensen *et al.,* 2003; Di Gregorio and Shane, 2003; Chapple *et al.,* 2005, Wong and Sing, 2010), ii) the level of research and research portfolio (i.e. Blumenthal *et al.,* 1996; Thursby and Kemp, 2002; O'Shea *et al.,* 2005[29]), iii) the institutional policies and norms (e.g. Jensen and Thursby, 2001; Thursby and Thursby, 2002; Caldera and Debande, 2010), vi) local (knowledge) demand conditions, vii) technology transfer offices (TTOs) and their characteristics (age, experience, staff, industry experience; e.g. Chucumba and Jensen, 2005; Belenzon and Schankerman, 2007; Conti and Gaule, 2009; Caldera and Debande, 2010), and viii) the technology transfer environment (national policy framework; financial investors, infrastructure and technology brokers, see Siegel *et al.,* 2003 and 2007; O'Shea *et al.,* 2008). Organizational practices and norms setting the basis for a culture of entrepreneurship are also important (Siegel *et al.,* 2003).

Intermediary organizations (e.g. incubators and technology brokers) can be key components to the development of technology transfer systems. Incubators can influence the set-up costs for new business and influence therefore spin-off activity (Siegel *et al.,* 2003; Rodeiro *et al.,* 2007). Another support structure for the formation of spin-off companies is science parks (Link and Scott, 2005). It is argued that geographical proximity facilitates information flows, reducing search and monitoring costs, and increasing the probability of successful industry-science relationships. However, the empirical evidence on the role of incubators is mixed and the empirical literature evaluating the role of science parks is to date limited (e.g. O'Shea *et al.,* 2005).

Based on the elements listed above and needed for technology commercialization, we can roughly summarize some of the main features of research and innovation systems in developing countries:

- PROs have traditionally been the main actors in national research activities (Figures 1-2). In middle- and low-income countries the government performs, on average, 45 percent of total

[29] Thursby and Kemp (2002) suggest that the orientation of research disciplines can play a distinctive role in technology commercialization. O'Shea *et al.,* (2005) provide evidence on the influence of research orientation in biological sciences, computer science and chemistry disciplines on spin-off formation rates. Lach and Schankerman (2008) report also evidence on the stronger involvement of biomedical and engineering faculties in patenting and licensing activity in US universities.

R&D (compared to 17 percent in developed countries). Universities' involvement in research is recent and their influence varies widely across countries (in emerging countries their role is gaining importance). On average, government funding is responsible for about 53 percent of total R&D in the middle-income countries for which data are available. 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.[30]

- In terms of research capabilities, in most developing countries, investment in S&T remains low- and human resources in S&T are insufficient (Figure 5). In 2007, R&D investment in low- and middle-income countries represented 0.35 of the Gross Domestic Product (GDP), whereas in high-income countries R&D investment represented 2.02 of the GDP. Exceptions are the BRICs (Brazil, Russian Federation, India and China) countries where public and private sector R&D investment has substantially increased during the last decade.

- There are few researchers and most of them are working in the public sector (Figures 3-4). Furthermore, middle- and especially low-income countries face great difficulties in retaining talented scientists and professionals given the lack of job opportunities, weak wages and poor infrastructure for research. Several countries have recently new policies to attract talents and link with scientists abroad (UNESCO, 2010).

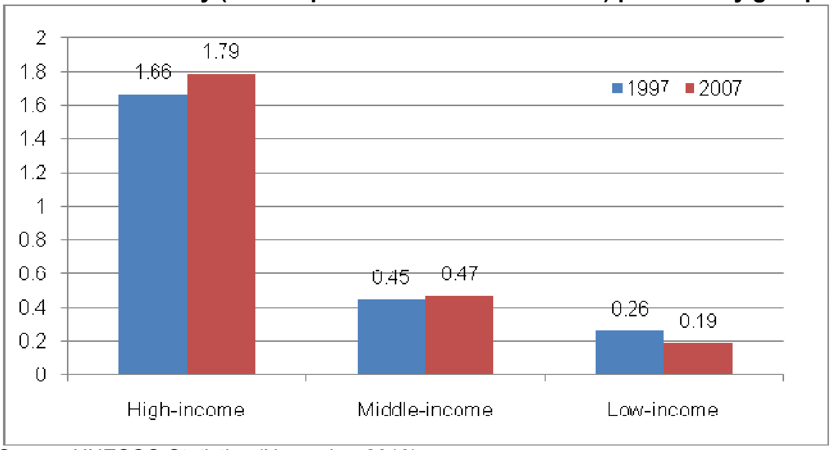
- This situation combined with a lack of absorption capacity in firms and their preference for incremental (or imitative) innovation and acquisition of foreign technology as primary innovation strategies, partially explains the fragmentation in national innovation systems (Navarro *et al.,* 2010; Anllo and Suarez, 2009).[31] Figure 6 illustrates the importance of technology acquisition in firms' innovation strategies. The majority of technology transfer has traditionally been limited to PROs and the nature of these linkages has been generally oriented towards irregular technical assistance rather than accomplishing technological development (e.g. R&D) activities (Correa, 2009).

- The constrained access to finance remains a major barrier to the development of innovation. Bank loans are out of reach for small and new firms, and the cost of capital is prohibitive for many firms. Venture capital funds have been launched in many middle-income countries (as well as India and China) by the state yet its impact is still small (for a discussion on China and Mexico, see, OECD, 2007; 2009, respectively). In particular, access to pre-seed capital remains a bottle neck for high tech startups.

[30] 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.

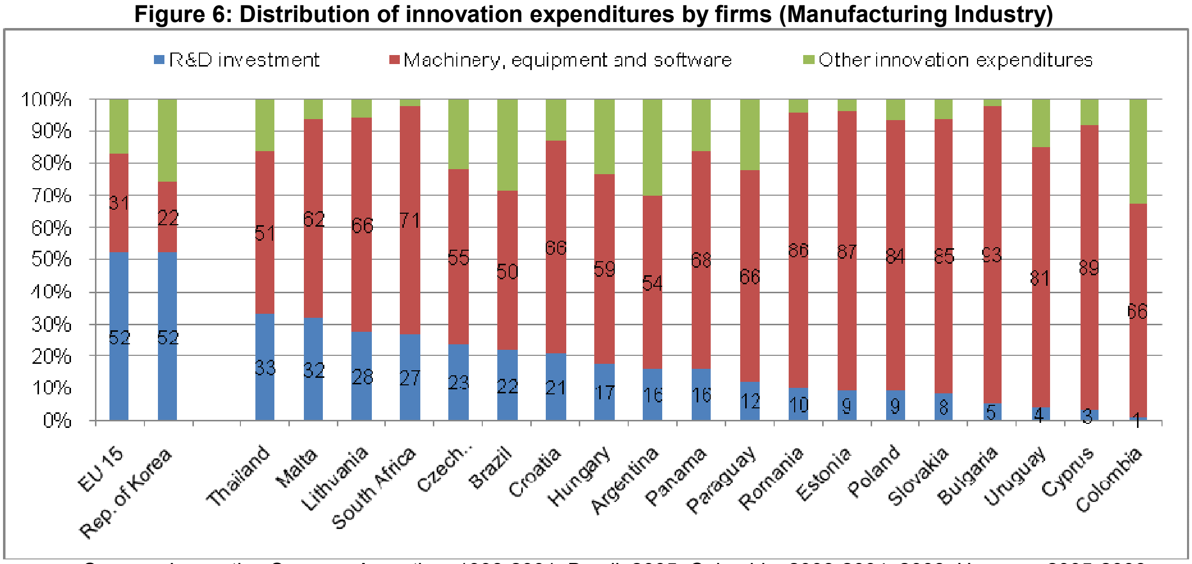
[31] Arocena and Sutz (1999) point out that industrial innovation in developing countries is highly informal, i.e. not products of formally articulated R&D activities.

Figure 5: R&D intensity (R&D expenditures relative to GDP) per country group



Source: UNESCO Statistics (November 2010).
Note: Missing information for 1997 was replaced with 1996 or 1995 (latest available); ibid for 2007. Averages per income group are simple means across countries per group.[32]

Figure 6: Distribution of innovation expenditures by firms (Manufacturing Industry)



Sources: Innovation Surveys. Argentina: 1998-2001; Brazil: 2005; Colombia: 2003-2004; 2008; Uruguay: 2005-2006; Paraguay: 2004- 2006; Thailand: 2003 and South Africa: 2002-04. Data for EU-15 countries are from Eurostat Chronos (Innovation surveys 2006); completed with data from OECD (2009) for Germany, Rep. of Korea and United Kingdom. For Estonia, Bulgaria, Cyprus, Lithuania, Hungary, Malta, Poland, Romania, Slovakia, Croatia and Turkey, data are from Eurostat Chronos, 2006.[33]

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[32] Please note that the indicator for the "Low-income" group should be read with care given the very small number of countries reporting information. High-income countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea (Rep.), Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom, United States, Croatia, Cyprus, Estonia, Israel, Kuwayt, Singapore, Slovenia and Trinidad and Tobago (2007). Middle-income: Algeria, Argentina, Belarus, Bosnia and Herzegobina, Botswana, Brazil, Bulgaria, Colombia, Costa Rica, Cuba, Kazakhasthan, Latvia, Lithuania, Malaysia, Mauritius. Mexico, Montenegro, Panama, Poland, Russian Federation, Serbia, Seychelles, South Africa, Turkey, Uruguay, Armenia, Azerbaijan, China, Ecuador, Egypt, El Salvador, Georgia, Guatemala, India, Indonesia, Mongoloia, Morocco, Pakistan, Paraguay, Philippines, Sri Lanka, Sudan, Thailand, Tunisia and Ukraine. Low-income: Burkina Faso, Ethiopia, Madagascar, Mozambique, Senegal, Tajikistan, Uganda and Zambia.

[33] Indicators refer to the Manufacturing Industry except for South Africa and Thailand whose indicators reported refer to manufacturing and services industries. EU (15): The indicator is the average share across countries. The EU-15 countries include Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom; data for Austria and Italy were not available.

According to a recent study on Latin American universities (PILA Network, 2009), the main limitations of knowledge transfer from universities to industries are as follows: i) the lack of research capacity in institutions (strong enough to offer technology solutions to firms' problems); ii) quality and technology requirements needed to compete globally; iii) unsupportive culture and willingness to collaborate with the productive sector; iv) limited recognition of technology transfer activities in curricula; v) universities do not account with the institutional infrastructure adequate to commercialize services and technologies; vi) having TTOs at universities, there is a lack of expertise and qualified personnel to deal with technology transfer management, and viii) lack of a normative framework and explicit policies to manage institutional linkages with the private sector.

1.7 Discussion

S&T and innovation conditions in middle- and low-income countries differ widely from those in developed countries, in particular in terms of R&D investment, scientific activity and patenting. The role of patents may play in enhancing the impact of scientific research on local economies and their use, may not necessarily be the same across countries. Their importance will depend on national conditions for technology transfer as well as the needs of industries and society.

There are several reasons that explain the limited impact of science on economic development in low- and middle-income countries. First of all, in terms of policy strategies, for a number of reasons, the need for solving basic economic needs such as poverty and health have traditionally placed science and technology as second order priorities. Second, middle- and low-income countries are a very heterogeneous group of countries where needs and conditions for technology transfer may widely differ. In most low-income countries, many of necessary elements for science to have an impact on industrial innovation and society are embryonic, while in middle-income countries the foundations exist but are weakly articulated (Arocena and Sutz, 1999; 2001; Gu, 1999). It is clear, however, that R&D capabilities in middle income countries (especially in BRICs) have substantially been improving during the last decade and opportunities to enhance technology commercialization through IP are emerging.

A number of issues remain to be tackled. There is evidence that scientific information is hardly used by firms to innovate and this is due in part to a weak R&D capacity of firms and lack of interaction between science and industry. Furthermore, in the promotion of technology transfer, and especially in the case of commercialization progress is needed not only in terms of increased funding but also with regard to institutional and cultural changes, which are required to make research more competitive and encourage researchers to participate in technology transfer activities. In recent years, several countries have taken meaningful steps to improve reward systems at universities.[34] Some countries have already started to modernize university and research systems by increasing autonomy, adopting performance evaluation plans, granting more competitive grants, and introducing new, flexible policies for recruitment and collaboration; e.g. China, Mexico and Kenya (see Flaherty *et al.,* 2010; Yusuf and Nabesima, 2007). Even new incentives and performance-linked criteria for researchers are being implemented. Major reforms in higher education systems have been undertaken in China (OECD, 2007) and South Africa (Wolson, 2007a; Sibanda, 2009), among other countries. In China, since the 1990s, the higher-education system has undergone important reforms including an increased decentralization and an update of curricula integrating innovation skills and industry demands in education programs (Wu, 2010a; OECD, 2007).[35]

[34] These include Cameroon, Botswana, and Zambia (UNESCO, 2010). In 2009, Cameroon created a permanent fund to boost salaries of university lecturers and researchers; and Zambia, in 2008, introduced allowances for academic staff at state universities to make salaries more competitive.

[35] Moreover, the Chinese public research system was downsized (i.e. the Chinese Academy of Science), rebalanced in favor of universities, and considerably modernized. In South Africa, universities have merged, becoming more

II. UNIVERSITY PATENTING AND POLICY FRAMEWORKS

Technology transfer policies at higher education institutions are relatively new in middle- and low-income countries. This section documents the different policy approaches and regulatory frameworks governing patenting and technology transfer at universities in 12 middle-income countries. In particular, we look at three major policy areas: i) policy framework enabling universities to own IP rights over inventions resulting from government funded research, and to commercialize technology; ii) policy incentives for researchers, namely a royalty sharing formula and the right to equity participation in spinout companies; and iii) policies aiming to develop a national infrastructure for technology transfer (i.e. technology transfer organizations, venture capital and incubation infrastructure), and skills needed for technology transfer management.

2.1 University policies and incentives to inventors

A wide range of policy approaches to technology transfer has recently been implemented in many middle-income countries with special emphasis on results from scientific research (e.g. Graff, 2007; WIPO, 2007; Correa, 2009). Policy approaches targeting technology transfer from universities range from higher education system reforms, the creation of cluster and science parks around academic institutions, promotion of networks and university-industry collaboration (through subsidies and R&D investment, fiscal exemptions, etc.), to the creation of specific laws regulating technology transfer.

In terms of policy frameworks regulating ownership of IP rights derived from government funded research, there is a policy convergence in vesting the rights to research institutions. Yet the regulatory mechanisms are very diverse. They can take the form of: i) national decrees and ministerial acts, ii) ownership clauses in patent law, iii) ownership clauses in labor law and government contracting laws*,* iv) ownership clauses in the regulation of national R&D systems (i.e. higher education laws, regulation of research institutes laws) and v) innovation and S&T laws. Some of these mechanisms require institutions to compensate researchers who invented or contributed to the IP through the sharing of royalties or equity participation in academic startups. The evidence reviewed in Section I suggests that while ownership policy reforms are not the sole factor influencing university patenting and technology commercialization, they contribute to raising awareness at higher education institutions and increasing their commitment to conducting technology transfer activities.

Enabling policy frameworks however is not sufficient to transform universities into more entrepreneurial institutions. The literature underscores the importance of providing incentives to those who participate and manage the technology transfer process (Siegel *et al.,* 2003; Siegel *et al.,* 2007). The study undertaken by Siegel *et al.,* (2003) identified three key impediments to university technology transfer in a study on American universities. The first was informational and cultural barriers between universities and firms. Insufficient rewards for faculty involvement (pecuniary and non pecuniary rewards such as credit towards tenure and promotion) were another impediment. The third problem was difficulties with staffing and compensation practices in the TTO.[36] To counteract these difficulties, institutional policies providing appropriate incentives and the strategic approach given to the valorization of research are fundamental to the creation of a proactive environment for technology transfer (Debackere and Veugelers, 2005). And last but not least, international experience shows that technology transfer needs special organizational arrangements in order to deploy third mission activities and serve as intermediaries between the

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efficient and achieving economies of scale and scope (Sibanda, 2009). University mergers are intended to make the system more effective, increase and standardize education quality and boost resource allocation.

[36]A high rate of turnover among licensing officers and insufficient business experience are among the main problems limiting performance of TTOs.

university and the external environment. TTO is a widespread institutional response to the need for management of technology transfer activities and industry links.

In the following paragraphs we discuss the importance of inventor incentives and the role of TTOs in fostering patenting (and IP in general) and technology transfer from academia. We highlight lessons from international experiences and economic literature.

- ***Inventor incentives***

The recognition of inventors' participation in the technology transfer process is crucial. Inventor revenue compensation can take the form of a fixed rate of revenues generated from the exploitation of IP and other technological activities or it can be a non-linear rate. It can also be a lump-sum payment. Other incentives to encourage researchers include awards, recognition in curricula, and equity participation in spinoffs, among others. There are justifications for the need to provide incentives to inventors. A large component of knowledge is tacit (non codified in blue prints) and idiosyncratic to its creator (knowledge and know-how embedded in persons). Success in technology transfer often requires direct involvement of inventors (e.g. Jensen and Thursby, 2001; Agrawal, 2006, Wright *et al.,* 2007). Further, researchers are normally adverse to administrative procedures and the time required for technology transfer activities (i.e. writing a patent application and conducting the state of the art), which can be weighty at early stages of university involvement in technology commercialization. There is substantial evidence supporting the positive role of royalty sharing in technology licensing and licensing revenues in high-income countries.

For US universities, Macho-Stadler *et al.,* (1996), Jensen and Thursby (2001), Link and Siegel (2005), Friedman and Silberman (2003) and Lach and Schankerman (2008) all provide evidence that higher royalty shares for faculty members are associated with more efficient technology transfer activities (and greater licensing income). Similar findings are reported by Debackere and Veugelers (2005) and Caldera and Debande (2010) for European universities. Researchers are not only motivated by economic incentives. Non-pecuniary incentives such as gaining reputation and prestige, as well as accessing funding and new ideas from industry, have been found to be equally (or even more) important. Survey studies by Göektepe and Mahagaonkar (2008) and Baldini *et al* (2007) provide evidence to support this hypothesis.[37]

Licensing to established firms is not always feasible for a number of reasons (Jensen *et al.,* 2003; Thursby *et al.,* 2001). When technologies are too radical and disruptive, and firms are not fully able to exploit such technology (because of the need for new technological skills), licensing such patents is a high-risk investment for established firms (e.g. Thursby *et al.,* 2001).[38] Shane (2002; 2004) studied the characteristics of licensed patents from MIT and compared characteristics of technologies commercialized through start-ups with licensing to established firms. He found that start-ups are more often used to commercialize new technologies that are radical, tacit, at an early stage and of general purpose. They also involve major technological advances and have strong IPprotection.[39] Based on case

[37] In a study of 2500 scientists affiliated to 67 laboratories from the Max Planck Society, they find that expectation by researchers to gain/increase reputation through commercial activities is correlated with their patenting and disclosure activities. Researchers would use such activities to gain academic promotion and industrial collaboration rather than financial gains. Baldini *et al* (2007) found similar conclusions in a study of Italian inventors.

[38] Thusby *et al.,* (2001), in a survey before 62 TTOs at US universities, found that 60% of respondents indicated that large firms were more likely to take late stage technologies and that small firms were more prone to exploit early stage inventions.

[39] In contrast, licensing to established firms is used to commercialize new technologies that are more incremental, codified, late stage and specific in purpose [or 'purpose-specific']. They also involve minor technical advances, provide moderate customer value and have weaker IP protection.

studies, Wright *et al* (2004) arrived at similar conclusions.

The greater the importance of tacit knowledge and know-how in new academic technology, the more difficult the absorption and use of technology by established firms is. University startups are a solution to commercialize breakthrough technology and bring it to the market. For that purpose, special incentives are needed for researchers such as the right to have equity in academic startups and preferential licensing. Di Gregorio and Shane (2003) have shown that in the US the ability of university inventors to take equity in start-ups (in lieu of licensing royalty fees) explains higher rates of start-up formation. Locket and Wright (2005) find that for UK firms the extent of start-up formation is positively associated with the extent to which its royalty distribution formula favors faculty members. In addition, surrogate entrepreneurs have also proven helpful for technology commercialization and firm creation (e.g. Franklin *et al.,* 2001; Lockett *et al.,* 2003). Franklin *et al., (*2001) studied start-up formation at universities in the United Kingdom (UK) and find that the universities generating the most start-ups are those that have the most favorable policies regarding external entrepreneurs. The authors suggest that a good approach for universities that wish to launch technology transfer start-ups is a combination of academic and surrogate entrepreneurship. Caldera and Debande (2010) also find, for Spanish universities, that those granting researchers leave of absence to set up a spin-off company are more successful in creating them. Similar results apply in the case ofuniversities with a stake in risk capital funds, which confirms the importance of universities' venture capital funds in bridging the financing gap for university-based spin-offs.

- ***The role of TTOs***

TTOs are dedicated to coordinating all the different aspects of technology transfer activities, from invention disclosures, development, diffusion and exploitation of patent policies, to the management of industrial liaison and start-up creation (e.g. Jensen *et al.,* 2003; Macho-Stadler *et al.,* 2007; Belenzon and Schankerman, 2007). The experience shows that, by facilitating the division of tasks among stakeholders, TTOs take the burden of IP administration and commercialization off researchers' shoulders, and by building reputation and networking competences they facilitate institutions' integration into technology markets (Siegel *et al.,* 2007). Activities by TTOs include, but are not limited to: i) evaluation of the quality of inventions disclosed, ii) support for patent and IP applications, iii) promotion of collaborative and contract research (search for partners as well as funding sources), and iv) support for researchers in the creation of university-based spin-offs, among others.

TTOs have been proven to be key factors in university licensing and start-up formation (e.g. Debackere and Veugelers, 2005; Caldera and Debande, 2010). Different studies have provided evidence of a positive effect from having a TTO on university patenting (e.g. Baldini, 2009; Della Melva *et al.,* 2010). Evidence of the number of TTO staff and experience (age) having a positive impact on technology transfer outputs has been reported by Thursby and Kemp (2002), Siegel *et al.,* (2003), Lach and Schankerman (2008) and Conti and Gaule (2009), among others. It has also been found that a university's success in technology transfer depends on the commercial capabilities of TTO staff, notably staff experience in business (Locket and Wright, 2005).

2.2 Policy frameworks in middle- and low-income countries

The first policy framework allowing universities to own IP rights over inventions resulting from state funded research and engage in technology commercialization was adopted in the United States. The American technology transfer model owes much of its configuration to the Bayh-Dole and Trademark Amendment Act enacted in 1980. This law entitled universities, nonprofit organizations and small firms, with the right to patent and exclusively license federally funded inventions. It also provided a series of policy rules for invention disclosure and patenting, required institutions to provide incentives for researchers, and promoted the creation of technology infrastructure (Henderson *et al.,* 1998; Mowery and Sampat, 2005; 2008).[40]

We now review the current policy framework in a group of 12 middle- and low-income countries. We have gathered information from ministerial reports, governments' websites, newspapers, economic studies and policy innovation reviews. The information reviewed suggests that policy frameworks in middle-income countries are mirroring international policy trends in the provision of IP rights to research institutions (PROs and universities), institutionalizing incentives for researchers, and the promotion of technology transfer infrastructure.

A fundamental factor influencing this evolution was the reinforcement of IP rights by the mid-1990s (for middle-income countries) and the early 2000s (the rest of countries) through their adherence to the TRIPs administered by the World Trade Organization (Cimoli and Primi, 2007; Zuniga and Combe, 2005). Among the major reforms undertaken were the expansion of patent protection to different technological domains; notably in pharmaceuticals and agriculture, and the extension of patent rights to 20 years as the statutory term, in line with standards in high-income countries. Equally important was the adoption of breed plant variety protection in many countries, mostly through their adherence to the *International Convention for the Protection of New Varieties of Plants*. In some countries, IP laws provided the starting point for the commercialization of public research when they established the legal rights for universities (employers) and PROs to own and exploit intellectual assets derived from their research activities.[5]

We can roughly identify three policy strands in our list of countries under study. In the first group of countries, there is no explicit regulation, but rather general rules defined in common law (intellectual property or patent law), and/or legislation regulating research institutions or government funding (i.e. through Ministry of Education). A second policy model consists of ministerial laws in the form of national innovation laws or S&T laws. A third model, adopted more recently in some emerging economies like Malaysia, South Africa and the Philippines, builds on the Bayh-Dole Act. This policy model explicitly targets the creation and management of IP rights and technology transfer. This typology does not exclude the possibility of policy and regulatory frameworks restricting ownership and commercialization activities (e.g. Argentina). Furthermore, there are also countries where there is no national policy framework but general guidelines for IP management and technology transfer have been published by government authorities along public support for creation of TTOs (e.g. Nigeria and Ghana).

As shown in Table 1, half of the countries under analysis have formally addressed the question of IP ownership through specific national legislation. The increasing policy attention to university patenting has motivated heightened awareness of global policy trends, and, in particular, a strong desire on the part of governments to enhance the impact of public research on economic systems. Shrinking federal spending on R&D is also at stake in some countries (Graff, 2007; Sampat, 2009a).

As in high-income countries, most of the countries examined here have laws requiring inventor participation in royalties and revenues derived from exploitation of technology. Other policy incentives spreading across countries are the public support for TTOs and formation of technology transfer managers, funding mechanisms to finance start-up formation and the creation of S&T parks. There is

[40] The Bayh Dole Act main provisions are: Universities are allowed to title inventions developed under federal funding; universities are required to file patents on inventions they elect; universities must have written agreements with faculty and staff requiring disclosure and assignment of inventions; universities must share a portion of revenue with inventors; excess revenue must support research and education; government retains non exclusive license to the invention and retain march-in right.

much more policy divergence across countries analyzed in terms of incentives for firm creation. In particular, policies regarding the right to equity participation and temporary leave allowance for firm creation are partially covered or absent.

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. China was among the first to adopt a policy framework in 2002. 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. 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.

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. Algeria, Egypt, Morocco and Tunisia have been working on drafts for similar legislation.

The passage of explicit laws in South Africa, Malaysia and Philippines aims to provide the innovation system with institutional instruments to develop a unifying policy of technology transfer, which was previously lacking or misarticulated. 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. By standardizing IP practices and providing incentives for technology transfer, these policies intend to systematize industry-science linkages and lay the foundations for a culture of entrepreneurship. Following the US, these legislations define the rights and responsibilities of both government agencies and research institutions in the ownership and management of intellectual assets. Obligations for universities defined in these legislations include the identification, disclosure, and protection of intellectual results, as well as their utilization and commercialization for the benefit of countries. Exceptions for government intervention are considered. Perhaps one of the most laudable aspects of the legislation in some developing countries like South Africa and India is that, unlike their US and European counterparts, they provide minimum levels of compensation for inventors. Countries that have promoted the creation of technology transfer units at the institutional level include Brazil, India, and South Africa. Countries that have enacted national decrees or laws stipulating that universities have the right to ownership of research results include China (1996; 2002), Brazil (1996; 2004), and Mexico (2009).

2.3 Country Cases

2.3.1 BRICS

Brazil

Technology transfer practices have been implemented in Brazilian universities since the early 1990s, although most of them were done informally. An initial regulation was enacted in 1996 (Law 9279) giving the right of ownership to universities on inventions generated by professors and researchers. Later, the *2004 Innovation Law* (Law nº 10.973) provides further incentives for IP exploitation and collaborative public-private research relationships,[41] including the provision of the faculty to universities to commercialize and manage IP from publicly funded research and the adoption of more flexible procedures to speed-up technology transfer and collaborate with firms (notably small and medium size enterprises).[42] The law also established the creation of TTOs -- at each university, or shared with other institutions, when necessary - and includes a chapter that specifically regulates the acquisition of IP by scientific institutions from independent inventors. The law also states that universities and PROs are required to share revenue with inventors. Accordingly, inventors must receive between 5-33% of royalties or licensing income.[43] The *2004 Innovation Law* also introduced incentives for collaboration and entrepreneurship.[44]

Russian Federation

The question of ownership by PROs and universities was defined in the 2003 revision of the Patent Law. Article 9 of the Patent Law updated in 2003 states that the right to patent an invention created under state funding belongs to the contracted research organization, unless the research agreement specifies that the right belongs to the government (Graff, 2007). Before 2003, through a Decree introduced in 1998, research institutions were in principle able to take IP rights over inventions resulting from work funded by the federal budget, but the government retained first rights to any IP. The decree also required all inventions made under federal funding to be recorded with the federal government. As a result, very few patents were sought through official channels. In 2007, a comprehensive federal target program was launched, known as *R&D in priority fields of science and technology development in Russian Federation for 2007–2012*, aimed at increasing research capabilities and technology transfer from research institutions. The program focuses on five priority technologies. Special attention is given to nanotechnology. In addition, several national programs have been launched to create high-technology parks.[45]

[41] The law established the provision of incentives for participation of institutes of S&T in the innovation process as one of the three pillars for national innovation catch-up. The other two are the creation of environments appropriate for partnerships between universities, technology institutes and enterprises, and direct incentives for firm innovation. The Innovation Law (Law nº10.973) was sanctioned in 2004 and regulated in October 2005.

[42] The legal framework regulating scientific institutions compels them, among other things, to undertake a public bidding process for the licensing of technologies. According to the new Innovation Law, universities and PROs will only be requested to publish a previous “request for licensees” for the purposes of transferring or licensing their technologies. With the new regulation, they are able to accelerate the process of licensing and selecting the best partners.

[43] As an example, the University of Campinas (UNICAMP) applies 33 percent to professors to researchers. Professors are also given a share of the income from any consultancy they perform.

[44] Researchers have been able to work in other institutions to conduct joint projects and request special leave (without pay) if they decide to become involved with a start-up company. The law encourages the public and private sectors to share staff, funding, and facilities such as laboratories. Until 2002, such collaboration was not officially permitted. Researchers have been able to work in other institutions to conduct joint projects and request special leave (without pay) if they decide to become involved with a start-up company. The law encourages the public and private sectors to share staff, funding, and facilities such as laboratories. Until 2002, such collaboration was not officially permitted.

[45] Currently, the government is investing in the creation of a new S&T business hub in the town of Skolkovo, near Moscow, that aims to be the Silicon Valley of Russian Federation. Tax deductions, subsidies, and co-financed investment are among the incentives for attracting business and linkages with local scientific institutions.

Table 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 Russian Federation 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 IP from 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: The National Science and Technology Plan	Only available for governmental institutions 60% (PRO)-40% (inventor)	NO National TTO (1997)

Source: Zuniga (2010) and feedback from WIPO's Innovation and Technology Transfer Section.

India

India is currently on its way to introducing its own Bayh-Dole Act legislation. The Utilization of Public Funded Intellectual Property Bill 2008, approved by the Union Cabinet and currently under consideration by the Parliament, would allow government-funded academic institutions to own IP rights over intellectual creation and commercialize the fruits of publicly funded research. The proposal has striking resemblance to the U.S. Bayh-Dole Act (Vartak and Suarastri, 2009). In addition to providing a set of rules for ownership and licensing, the law would also establish a reward system, with provisions for distribution of royalties and licensing fees. Accordingly, individual inventors should be paid at least 30 percent of any royalties stemming from licensing (otherwise some requirements are demanded). Individuals, however, are left with few options of determining how their invention can be used.

The bill will also encourage research institutions to establish their own technology licensing offices in whatever form and to adopt their own policies on IP rights management and technology transfer, in accordance with current legislation. To date, except for a handful of universities and colleges, the majority of Indian universities do not have a technology licensing office, which undoubtedly restricts inventions to the university laboratory (Stephen, 2010). The bulk of IP and technology transfer expertise remains located in government agencies, particularly in the Council for Scientific and Industrial Research (CSIR). With respect to firm creation, most publicly funded institutions in India have traditionally not been allowed to hold equity in ventures. This restriction is being changed through the creation of separate entities within these organizations and through the creation of incubators.

China

Since the mid-1980s, the Chinese government has implemented as series of laws to foster technology transfer from public research (Guo, 2007; Wu, 2010a).[46] In 1985, the *Decision on the Reform of Scientific and Technological Systems* issued by the State Council on Technology Transfer allowed universities to manage R&D programs and transfer technologies to firms (mostly state firms). Yet the state retained ownership of IP under Chinese law, but universities could still use their inventions (Graff, 2007). The *S&T Advancement Law* and the *S&T Findings Conversion Law* of 1998 provided provisions for inventor compensation and incentives for firm creation. The right of ownership and commercialization of research findings funded by the government was given in a ministerial decree in 2002, *Measures for Intellectual Property Made under Government Funding.*[47]

This legislation also states that the university or institute must share with the inventor(s) a portion of any revenue received. Other provisions include reserved rights granted to the state to own IP for compelling reasons (security or other vital interest of the public); and the right of the state to a nonexclusive, royalty-free license to make use of inventions created using government funding. Under certain circumstances, the government can require the university or institute to grant a license to a third party. This legislation was accompanied by official directives that strengthened incentives for the development of university enterprises. In 2001, the State Economic and Trade Commission and the Ministry of Economy jointly set up the first group of national technology transfer centers in six universities to promote the commercialization of technological achievements.

South Africa

Universities and PROs have been able to patent according to the Patent Law. However, patenting and commercialization practices have not been uniform across institutions. Although most universities prefer to take ownership of IP whenever possible, about 58 percent of their research funding comes from industry contracts, which typically stipulate industry control of IP rights resulting from the funded research projects (Wolson, 2007a). Therefore, most universities have maintained flexible approaches and turn down ownership of IP as needed to get industry funding.

Major steps in boosting technology commercialization from public research organizations were initiated in 2002, when the government published the *National Research and Development Strategy.* It emphasized the need for patenting, particularly innovations emanating from publicly funded research institutions, namely universities and research councils. In response to the diversity of IP practices across institutions and to clarify rules regarding ownership and licensing, in 2008 the government presented the proposal *Intellectual Property Rights from Publicly Financed R&D Act*. This law was implemented in August 2010. Influenced by the US *Bayh-Dole Act*, the South African Act defines a number of obligations, ranging from disclosure and IP management to the creation of TTOs. Each institution is expected to have an internal TTO, which reports to a central organism, the National Intellectual Property Management Office, which will be created to promote the objectives of the Act. The Act rewards inventiveness by entitling inventors in research institutions to a minimum of 20% of the gross revenues accruing to the institution for the first ZAR 1 million and a minimum of 30% of net revenues thereafter.

[46] The first technology incubator program (the Torch Program) was launched in 1988. It provided financial support to the creation of high-tech business incubators to promote the commercialization of S&T findings.

[47] Close initiatives though were first launched in the 1997 S&T law, i.e. Stephen, 2010.

2.3.2 Other Countries

Kenya

Currently, there is no specific legislation regarding IP creation and commercialization by universities and PROs in Kenya.[48] Institutions are left to themselves to adopt institutional policies and capacities to assert ownership, as long as the institutions operate according to the basic requirements of national IP law (Graff, 2007). Though several universities and research institutions have started to adopt their own institutional policies for IP and technology transfer and are currently engaged in creating IP offices. Moi University established Moi University Holdings Ltd., a fully owned subsidiary with a TTO to manage the university's intellectual property. Kenyatta University, Karu and Egerton University have also developed or have currently drafts of IP policy at advanced stages. The role of IP is however very limited in technology transfer and patenting is at an embryonic stage.

Kenya is the top third country in the group of Sub-Saharan countries, after South Africa and Namibia, in number of scientific publications (UNESCO, 2010). In terms of patents, patenting by nationals is almost inexistent. In 2004, only 15 patent applications were filed by research institutions and only 2 were coming from inventors at universities (Ogada and Mbayaki, 2006). The country still faces important challenges in strengthening its research and innovation capacity. Industry science linkages are yet to be developed. A study by Bwisa and Gacuhi (1999) documented main weakness and difficulties for commercialization in Kenyan research institutions. Accordingly, some of the major handicaps have been the lack of enabling institutional arrangements to enhance diffusion and adoption of innovations and technologies; and the poor links between research institutions and users of innovations.[49]

Nigeria

Nigeria is in process of establishing IP and technology transfer offices in all institutions of higher education and research in the country. Since 2001, the government has given increased importance to S&T in the definition of economic development goals, the creation of key industries and solutions in health, energy, and agriculture. The research and university systems date from the 1920s-40s when the country was a British colony. Nowadays Nigeria has 104 universities, 27 federal, 36 state and the rest private and 66 R&D institutes (UNESCO, 2010).[50] However, most of R&D with potential of commercialization has been carried out by government-owned research institutes and only a limited number of university research reaches the commercial state (Ogbu *et al.,* 1995).

In terms of policy framework, there is no a specific law on IP creation at public funded research institutions. Instead, regulations are set within Federal Research Institutes. Recently, the National Office for Technology Acquisition and Promotion[51] (NOTAP) emitted the *Guidelines on Development of*

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[48] Kenya joined the World Trade Organization and became signatory to TRIPs in 1995. The country joined the UPOV in 1999, although protection for seeds and plants varieties was implemented in 1994.

[49] They inquired researchers at four research institutions (15 heads of departments and 150 lectures/technicians) and found that only 40% of the departments covered reported having a R&D policy. A similar proportion declared to be aware of a general research policy prevailing at the institution and 25% of the departmental heads declared to be aware of university-industry links whereas only 22% of lecturers and technicians do so. Furthermore, about half of those reporting having links declared that those relationships were starting and could not be evaluated.

[50] Nowadays, Nigeria is responsible of 11% of publications in Africa, just after South Africa and the country has the largest number of researchers in the region (yet in terms of researchers per capita is fifth place in Africa behind Botswana, South Africa, Senegal and Guinea; UNESCO, 2010).

[51] NOTAP is a technology brokerage organization that was established by the Federal Government of Nigeria by Decree No. 70 of 1979. This organization is involved in commercialization of inventions and R&D results, promotion

Intellectual Property Policy for Universities and R&D Institutions. Research institutions are encouraged to build on this document to formulate their own institutional IP policy and adopt revenue sharing policies accruing from IPs amongst the inventor(s) at agreed ratios (NOTAP, 2011). These guidelines explain how each R&D institution could formulate and implement their IP policy to protect tangible research products such as inventions, industrial designs, know-how, etc., in order to make them demand driven and economically viable. ItIt also aim at creating public awareness and promote utilization of IP for the benefits of the society as well strengthen research-industry linkages through the establishment of Intellectual Property and Technology Transfer Office (IPTTO).To date, the NOTAP has established 28 IPTTOs in universities, polytechnics and research institutions in Nigeria, to promote interaction and strengthen the linkages between research institutions and industries.

Argentina

Precedents of university technology transfer regulation in Argentina date from early 1990s. The 1990 Law 23.877 on the Promotion of Technological Innovation and the 1995 Law on National Higher Education provided certain conditions for institutional ownership and transfer of IP results at universities and public research institutions (Graff, 2007; Felice, 2002; Schugurensky and Naidorf, 2004). The 1990 Law 23.877 established the possibility of creating Units of Technological Liaisons (*Unidades de Vinculación Tecnológica*). This legislation also opened the possibility of approving additional monetary compensations to a scientist involved in a research project funded by industry. Article 59 of the Higher Education Law provided the financial autonomy of national universities and their right to seek additional sources of revenue from the provision of services, products, contributions, and any other resources, including technology transfer and commercialization. It also allowed research institutions to create, participate, or associate with firms for the purpose of promoting technological innovation.

Although these laws do not explicitly include rules on revenue sharing for inventors publicly funded research, the industrial property law set out general obligations (Lima, 2004). The 1995 *Law on Patents of Invention and Utility Models* states that employees who are authors of inventions have the right to a supplementary economic remuneration, if their personal contribution to the invention and its importance to the firm clearly exceed the explicit or implicit contents of their contract or work relationship.[52]

Enhanced support to university-science linkages emerged in 2002, when the government launched the *National Program for the Support and Strengthening of University Linkages with Industry*. Under this program, new incentives were given to encourage public-private collaboration and the movement of researchers between scientific institutions and industry. In terms of ownership of IP rights, however, the policy framework is complex. There are normative rules of administrative nature, in particular those regulating IP creation at the *Consejo Nacional de Investigaciones Científicas y Tecnicas* CONICET) –the main institution dedicated to the promotion and execution of scientific research-, that requires affiliated researchers to provide IP rights resulting from research funded by CONICET. TTOs of individual universities may establish individual agreements with CONICET for the assignment and management of

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of locally generated technologies, and dissemination of technology information. In addition, NOTAP conducts the assessment of technologies for companies that wish to acquire industrial plants, and assists in the negotiation of the purchase.

[52] In a study by the Ministry of Science, Technology and Productive Innovation (SECyT) (2003), were published the results of a workshop on the use of IP by national organizations of S&T. The findings were the following. Patenting in Argentina and its commercialization has been hindered by several factors: the lack of legal procedures to recognize inventors' participation in the exploitation of technology; absence of financing units for projects at pre and post-competitive stages; appropriation of intellectual results by foreign commercialization organizations; and more in general, the diversity of norms and procedures regarding ownership and commercialization of inventions at public research institution.

particular inventions.

Malaysia

In Malaysia, commercialization of public research began with the *Sixth Malaysia Plan* (1991-1995), which emphasized that public R&D programs should become more market oriented by exploiting the commercialization of research and technology (Govindaraju, 2010). The following editions of the Plans continued these efforts. In 2007, Malaysia adopted the second *National Intellectual Property Policy*, and in 2009 it adopted the *Intellectual Property Commercialization Policy for Research & Development Projects Funded by the Government of Malaysia*. The latter states that research institutions are entitled to ownership rights over inventions. This legislation mirrors the BayhDole Act and intends to promote the management and commercialization of research outputs at public research organizations and universities. It provides rules for ownership of IP, technology acquisition and IP most often firms establish technological cooperation agreements with clients and suppliers rather than universities law was subjected to a public debate including research and higher education institutions.

The law is unique since it considers six cases for patent ownership, including sole government ownership, sole university (or other research institution receiving funding) ownership, joint institutional ownership (research institution and government) and third-party co-ownership. Employers are required to share revenues with researchers, in accordance with a distribution table (first RM250,000; inventor: 100 percent; above RM5,000,001: inventors: 40 percent and institutions: 60 percent). Other incentives provided by the government include payments related to disclosure, filing of patents and grant of patents.

Several TTOs have been set up at leading universities and research institutes. Recent national innovation programs explicitly target commercialization of research at public research and higher education institutions through a series of policy instruments. The second *National Plan for Science and Technology Policy 2002-2020*, adopted in 2003, set out a clear strategy of developing partnerships and fostering commercialization of R&D outputs.[53] To date, Malaysia has had few successful cases of patenting and technology commercialization. However, its IP creation and commercialization efforts have been fairly limited. Successful commercialization in PROs is limited to a few organizations, namely the Malaysian Palm Oil Board, the Rubber Research Institute of Malaysia (RRIM), Universiti Putra Malaysia (UPM), and Universiti Sains Malaysia. These institutions have better linkages with industry (Govindaraju, 2010).[54]

Mexico

As in other middle-income developing countries, such as India and Brazil, most of the technology transfer in Mexico emanated from research institutions have been limited to PROs and institutes of technology, with only minor participation of universities. In terms of policy framework for IP creation, Mexico has a number of laws and regulations allowing and governing the use of patent rights by publicly funded research institutions. In several cases, federal research institutions have their own internal laws for technology transfer (e.g., *Ley de los Institutos Nacionales de Salud: Transferencia de technología en el*

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[53] Underpinning this strategy are four specific capacity-building targets: S&T institutional capacity, commercialization of R&D output, human resources' development, and generating a culture of techno-entrepreneurship. The program requires the creation of one-stop business units at all public-sector R&D institutions to handle business relationships with private companies and commercialize their respective research projects and results. The policy framework also provided authority for universities and PROs to corporatize their institutions. The first few institutions that were corporatized are SIRIM (SIRIM Berhad; formerly Standards and Industrial Research Institute of Malaysia (SIRIM)), and the Malaysian Institute for Microelectronics Systems (MIMOS).

[54] For further details on the Malaysian case, see Govindaraju (2010): http://www.techmonitor.net/tm/images/d/dd/10nov_dec_sf3.pdf

ambito de la salud, Articles 16 and 19), including statutes allowing affiliated research centers and departments to establish norms for the use of revenues generated by or derived from research. It also determines the rules and percentages under which the personnel participating in projects can benefit. In some cases, the regulations include norms governing the commercialization of IP. Article 163.5 of the Federal Labor Law provides general legal rules under which inventors are entitled to compensation derived from the exploitation of inventions. Accordingly, institutions should acknowledge the moral right of inventors to appear as "authors" and receive a supplementary compensation determined by common agreement of the parties.

The *Science and Technology Law* of 2002 emphasized the importance of improving university-industry linkages and increasing investment in research.http://co107w.col107.mail.live.com/mail/RteFrame.html?v=15.4.3106.0520&pf=pf - ftn2 The *Science, Technology and Innovation Law* of 2009 went further in the support to industry-science linkages and explicitly stated the development of knowledge transfers units (*unidades de vinculación*), among other public policies. Accordingly, research institutions including universities are required to increase participation in technology alliances, consortia, and in the creation of new private technology firms within which researchers from centers can be incorporated. The terms and conditions for such associations are to be left to the managing organs of the institutions. With respect to inventor compensation, the 2009 law states that institutions can pay inventors up to 70 percent of the receipts derived from IP generated by their inventions.[55] Yet entrepreneurship by researchers is still very limited, as there are no clauses in the *Federal Law on Labor and Responsibilities of Public Officials* that allow for participation in business creation and permit flexibility for taking temporary leave. In terms of patenting, the impact of some of the new initiatives is constrained by the lack of expertise in managing and negotiating IP transactions at universities, and the lack of intermediary institutions that could bridge the gap. Public-private initiatives have been launched to tackle this problem.[56]

The Philippines

In 1987, the Department of Science and Technology (DOST) developed guidelines for IP management and created the Technology Application and Promotion Institute (TAPI) to provide centralized services in technology transfer from public research institutions (Maredia *et al.,* 2000; Graff, 2007).[57] A central University Intellectual Property Office for the University of the Philippines was established in 1997 to coordinate offices at its six campuses. The *National Science and Technology Plan* of 2002 emphasized the importance of linkages between universities, industry, and government though the creation of a fund for technology transfer.[58]

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[55] At the National Autonomous University of Mexico (UNAM), the Rule on Extraordinary Revenues for employees establishes that academics will receive 40 percent of revenues derived from royalties, patents, or licensed technologies.

[56] In 2010, a non-profit association, ADIAT (*Asociación Mexicana de Directivos de la Investigación Aplicada y el Desarrollo Tecnológico*), launched a training program for the formation of technology transfer managers.

[57] TAPI is the implementing arm of the DOST in promotion the commercialization of technologies. It undertakes contract research, particularly at the pilot plant and semi-commercial stage; provides technical consultancy, including engineering design services, patenting and licensing services; and provides grants and/or venture financing for new and emerging projects. It administers the Invention Development Assistance Fund (IDAF) and the Inventors Guarantee Fund (IGF) for assisting inventors in the development and commercialization of inventions. Source: http://www.dbm.gov.ph/opif2009/dost-tapi.pdf

[58] The Plan attached importance to the transfer and/or adoption of technology by creating the Technology Innovation and Commercialization Fund (TECHNOCOM) and the Small Enterprise Technology Upgrading (SET-UP) Programs. In addition, a Venture Financing Program is also being put in place in order to accelerate the commercialization of new technologies by providing funding.

In 2009, the Congress approved the Philippine technology transfer bill entitled *An Act Providing the Framework and Support System for the Ownership, Management, Use, and Commercialization of Intellectual Property Generated from Research and Development Funded by Government and for Other Purposes*". According to government officials, such legislation was deemed necessary because of the lack of well-defined and unifying policy on technology transfer, insufficient investment in technology transfer and commercialization, and the lack of well-defined IP regimes in R&D institutions. In addition to statues for ownership, disclosure and management, it provides clauses for the management of IP from R&D performed by public institutes through their own budget, management of conflicts of interest, rights for commercialization by the researcher, and the establishment of spinoff firms. Yet, unlike the Indian and South African acts, it does not stipulate revenue-sharing rules. Accordingly, the sharing of revenues between institutions and researchers shall be governed by an employer-employee contract or other related agreements and laws. The labor legislation for S&T public servants, however, provides some rules. For researchers working in PROs, regulations on royalty sharing are spelled out in the 1997 *Magna Carta for Scientists, Engineers, Researchers, and other S&T Personnel in the Government* (Republic Act, No. 8439, approved in December 1997).[59] Provisions for recognition of researchers' work in the private sector are also stipulated.

Thailand

In Thailand, there is no specific legislation defining ownership and commercialization rules for research funded by the federal budget at higher education institutes and PROs, effectively leaving them free to develop their own institutional IP policies. The university system is in the middle of an important transformation. Academic entrepreneurs are encouraged to secure formal rights through IP rights, and universities are shifting toward increased autonomy from the government and closer engagement with industry (Brimble and Donor, 2006). The largest universities have started to create their own IP guidelines and policies.[60] At the same time, they have been pressured by the government to seek alternative sources of funding and commercialize R&D outputs. Offices for IP management and transfer (Technology Licensing Offices) have been created at most important research centers and universities, including the National Science and Technology Development Agency, Rajamangala University of Technology Thanyaburi, Burapha University, and King Mongkut's Institute of Technology Ladkrabang. However, management of the intellectual property portfolio is still a relatively new phenomenon for many universities in Thailand.

[59] Section 7 stipulates that S&T scientists, engineers, researchers and other S&T personnel shall be entitled to receive a share of the royalties subject to the guidelines of the Department. If the researcher works with a private company and the program of activities to be undertaken has been mutually agreed upon by the parties concerned, any royalty arising there-from shall be divided according to the equity share in the research project.

[60] The share of royalties (arising from patents, copyrights, and other IP rights) shall be on a 60 percent-40 percent basis in favor of the government and the personnel involved in the technology/activity which has been produced or undertaken during the regular performance of their functions.

III. PATENTING TRENDS IN MIDDLE-INCOME COUNTRIES

In this section we describe the current trends in patenting activity at PROs and universities, and discuss the main features for a group of middle-income countries. Based on national statistics, recent research studies, and our own calculations made in collaboration with the Economics and Statistics Division of World Intellectual Property Organization (WIPO), we present a statistical assessment of the most important trends in international patenting, based on Patent Cooperation Treaty (PCT) data from the *WIPO Patent Statistical Database* from 1980-2010. We distinguish between geographical and technological trends as well as differences in co-ownership patenting between high- and middle-income countries.

3.1 Patenting Trends by Universities and PROs

- ***National Filings***

As reported in Section I and by UNESCO (2010), several middle-income countries have progressed in terms of scientific and technological outputs during the last decade. Patenting by domestic residents at national and international offices in emerging economies has increased, especially from China and India. Patenting by scientific institutions is playing a meaningful role in some middle-income countries although statistics measuring this evolution is scarce. Yet to date, few countries in the world record patenting activity by universities in national statistical reports. Moreover, few nations have conducted studies documenting the state and evolution of patenting at national research institutions. We have gathered information on patenting at national patent (or IP) offices from five countries Brazil, China, India, South Africa and Mexico. We have relied on indicators from different sources: national reports on the state of patenting (China and South Africa), statistical reports by national institute of intellectual property or national patent office (Mexico and Brazil), and recent studies conducted by researchers (India and South Africa). We then report indicators of patenting activity by universities and PROs, based on the number of filings at national patent offices.[61]

It is important to look at national patenting activity, notably in the case of middle- and low-income countries, as filing at domestic offices is often the most commonly used channel for patenting. As is well - known, protection at international offices is costly for some institutions (and firms) in middle- and low-income countries. However, it is also true that patenting through the PCT is expanding worldwide, and middle-income countries are increasingly using this channel for protection (OECD, 2009b).

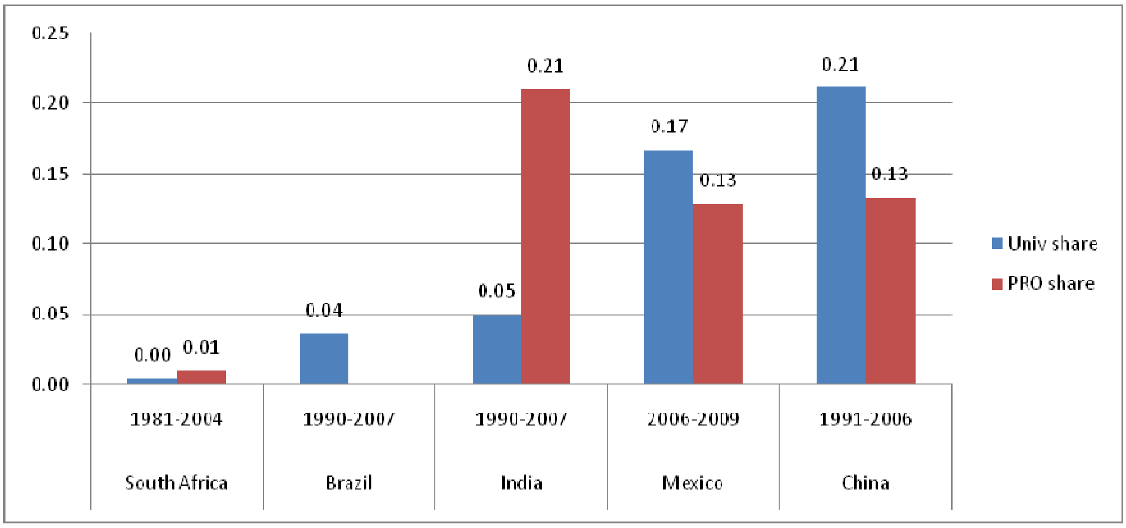
Figure 7 displays the share of university and PRO patent applications filed by domestic institutions in total resident filings at national patent offices for the countries mentioned above. Readers should take into consideration that periods differ across countries according to the availability of information.[62] Counts of patent filings by resident organizations can be interpreted as indicators of domestic technological innovation. Care should be taken when reading these Figures, as regulatory frameworks differ across countries, patenting procedures (e.g. processing and time for delivery of grants) and practice, enforcement of rights, as well as national policies framing innovation and patenting (e.g. subsidies for

[61] In this group, the exception in data is India whose indicators refer to filings by sector in total filings made in the world by Indian residents (Gupta, 2008).

[62] Data for Brazil are from Mai de Oliviera (2010), combined with data on total resident filings from WIPO (WIPO Statistics Database, January 2011). Data for India are from Gupta (2008) and data for Mexico have been provided by Instituto Nacional de la Propriedad Intelectual. For China, data are from Ministry of Science and Technology (S&T Statistics Databook, various years). Data for South Africa are from The State of Patenting in South Africa – Special Report, published by the Innovation Fund (2007) combined with information from WIPO (Statistics Database, January 2011). For South Africa, total resident filings from recent years are estimates.

patenting and R&D investments). Comparison of statistics across patent offices should be made with care.[63]

Figure 7: Patent filings by scientific institutions at national patent offices (as share of total resident filings at national offices)



Source: Years reported are filing years. Data are from: Mai de Oliviera (2010) for Brazil, Gupta (2008) for India combined with PATSTAT, INPI (2010) for Mexico, China (Ministry of Science and Technology S&T Report). For South Africa, data are from the Innovation Fund (2007) combined with information from WIPO (Statistics Database, January 2011). For South Africa, total resident filings for recent years are estimates based on WIPO Statistics.
Note: Direct country comparisons are not advisable as the methodologies and years vary country by country, and because some sources are more reliable than others.

According to data gathered and reported in Figure 7, Brazil and India have similar shares of university ownership in total resident patenting (4 and 5%). China has the largest participation of universities in total resident filings within this small group of countries. Universities in China represent 21% of resident filings during the period 1991-2006. India shows the most intense activity in terms of PRO patenting with 21% of resident filings corresponding to patents owned by scientific institutions. The participation of both universities and PROs in total resident filings in South Africa is less than 1%. This share is probably higher if we consider data from more recent years. It must be noted that the volume of patenting differs widely across nations. According to the data gathered, in 1991-2006, Chinese universities filed 64,768 applications at the domestic patent office, whereas in Brazil 1,978 applications were made respectively during the period 1990-2007. In South Africa, 520 applications were filed by universities, and 1,294 by PROs over the period 1981-2004.

As in high-income countries (e.g. Lissoni *et al.,* 2008), academic patenting in developing countries – in the sense of inventions originated by academic inventors – is not fully captured by university patents (owned by institutions). Academic researchers may appear as inventors in firms' patent filings as a result of university-firm collaboration, research contracting with PROs and with firms, or because of unofficial links between researchers and industry. Recent evidence for Argentina is provided by Raffo (2009). Accordingly, only 77 patents are identified under ownership of the largest PRO (CONICET), but after including patents from CONICET, which funds most of the research at public institutions, that include inventors from universities, the number of inventions by academics increases to 491 patents filed at the

[63] As described in the OECD Patent Statistics Manual (2009a), national (and regional) patent indicators measuring activity at country offices suffer from home bias as local residents enjoy certain advantages in the processing of patent applications; e.g. better knowledge of procedures, closeness to institutions, among others.

national office (and to 2,962 patents filed worldwide).

Figures 8 and 9 illustrate the growing university patenting activity in Brazil and China. 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. Overall, there has been general growth in patenting, led notably by firms. In China, university patenting overtook patenting by PROs in 2002 (when the Chinese version of the *Bayh Dole Act* was passed) and has picked up speed in recent years. However, as explained in the previous section, patenting by universities began in the mid 1990s after the launch of *Project 211* (in 1995) and *Project 985* (in 1998) programs, when universities began to provide stronger incentives for faculty research and commercialization (Wu, 2010a).[64]

Figure 8: Number of patent filings by universities and PROs in China (filings at SIPO)

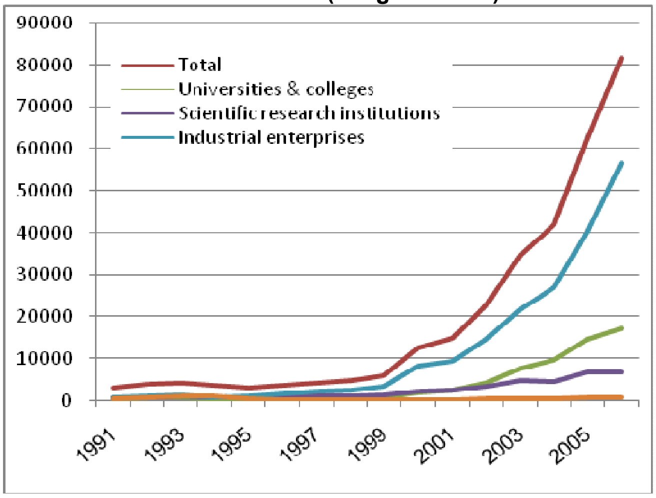
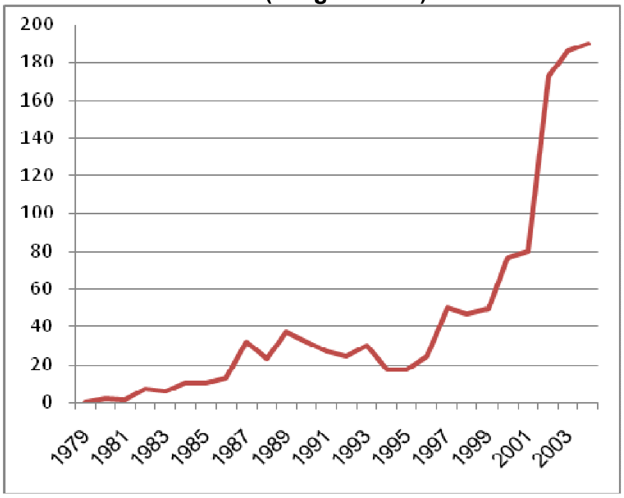


Figure 9: Number of patent filings by universities in Brazil (filings at INPI)



Source: Data for China are from S&T report from the Ministry of Science and Technology (several years). Data for Brazil are from Costa Povoa (2006).

In Brazil, the increase in university patenting in Brazil closely matches the policy reforms initiated in 1996 (Maia de Oliveira and Velho, 2010). Some studies also report that patenting was further strengthened with the passage of the 2004 *Innovation Law*, which provided further incentives for researchers and made creation of TTOs obligatory. During the period 1990–2001, there has been a 29.5 fold increase in applications and 4.01 fold in grants (Pinheiro-Machado and Oliviera, 2004). Pinheiro-Machado and Oliviera (2004) explain that the increase in academic patenting is largely related to greater scientific production; a threefold expansion is reported in the number of publications by the most productive universities over the period 1990-2001. Other factors contributing to this rise include changes in the Brazilian legal framework related to IP (WTO accession and adherence to TRIPs in 1995), increase in the intensity of academic research and investments in graduate studies, and the growth in the number of researchers (more PhDs trained annually).

It should be noted that increases in university patenting may reflect not only a stronger propensity to patent -- facilitated by policy frameworks and other institutional reforms - but also a reallocation of

[64] Incentives include economic awards, evaluation performance, university ranking, and the creation of liaison offices at higher education institutions. Researchers receive university support for patenting, obtain favorable positions in royalty sharing, and get additional assistance through incubator programs in university science parks (Wu, 2010a).

patenting across institutional sectors. In some cases, instead of seeing increased academic inventive activity by academics, we might see a shift away from patents owned by PROs (who sponsor research) to universities. A shift in sector allocation has been reported in France (Della Malva *et al.,* 2010) and Germany (Von Ledebur *et al*., 2009); Frietsch et *al.,* (2010) by studies looking at changes in ownership of inventions created by academics. There is also a noticeable decrease in patenting by individuals in China (Motohashi, 2008) to the benefit of the private and academic sector. The decrease in the individual inventors' share may reflect increased technological activity by organizations and an enhanced capacity to appropriate inventions, reflecting the new policy frameworks and IP management in organizations.

Recent studies have documented the growth of patenting by Chinese and Brazilian universities and have expressed concerns about the quality of patent filings and their use in technology transfer (Guo, 2007; Luan *et al.,* 2010; Maia de Oliveira and Velho, 2010). These studies stress the lack of a strategy of selectivity in patenting and poor use of technical and market assessments. Guo (2007) argues that the rapid growth in university patenting in China reflects in part the increased propensity by researchers and institutions to use patents as a way of enhancing their reputations rather than for actually transferring technology. Accordingly, rates of technology transfer and commercialization, while difficult to observe, remain low. A similar conclusion is reached by Luan *et al* (2010). For Brazil, Maia de Oliveira and Velho (2010) argue that a significant proportion of Brazilian academic patent applications are not transformed into grants and few patentability assessments are made at TTOs. The impetus for patenting is also motivated by the increasing recognition of patenting as a measure of university and research performance.[65]

3.2 Patenting by BICS (Brazil, India, China, and South Africa)

We distinguish some other features in patenting by universities and PROs, and summarize as follows:

- In Brazil, as discussed by Pinheiro-Machado and Oliviera (2004) and Del Marco and DeFreitas (2010), university patenting is concentrated in a few public scientific institutions, mostly public (state universities are more intensively involved in patenting) and largely confined to the South East region, namely the State of São Paulo (80% of patent applications at the national office). Concentration of patenting activity in the South East region is explained by the concentration of researchers, public investments, and scientific and technological institutions in this region. The main university patentees are University of Campinas (UNICAMP), University of São Paulo and São Paulo State University, the three universities located in the State of São Paulo. Nowadays, UNICAMP is the leading domestic patentee in Brazil. The largest public sector patentee is EMBRAMAP. Indicators about total patenting by PROs are unfortunately not available, which limits comparability between universities and PROs.

- Patenting in India began around the mid-1990s, influenced by changes in the economic and policy environment, especially by the adoption of the TRIPS agreement in 2000 through the World Trade Organization (Gupta, 2008). Compared to the 1990s, India's patent output grew at a much faster pace during 1999-2007. The industry sector is leading this patenting growth, consistent with firms' increased technological capabilities and competitiveness.[66] According to a

[65] Dalmarco and de Freitas Dewes (2010) explain that a significant number of academic applications are abandoned due to the lack of specialized staff to help with writing and processing the application. Accordingly, most universities file patent applications without knowing whether there will be any commercial interest in them, and as a result, they are unable to license filed patents. Programs are currently in place to strengthen skills and resources at TTOs in Brazil.

[66] Firms' share in patenting grew from about 40% of patents in 1990-1999 to around 60% of patents in 2000–2007

recent study (Gupta, 2008), 5% of patents granted worldwide come from the university sector, whereas the government sector is responsible for 21%. Of the Indian public sector firms, Indian Oil Corporation, National Research Development Corporation, and Steel Authority of India Limited are the major patentees during 1990-2007.

- The Indian Institutes of Technology, Indian Institute of Science, Indian Institute of Medical Sciences, and the University of Delhi are the leading participants from the university sector. From the government, the Council of Scientific and Industrial Research (CSIR) is the largest domestic patentee with more than four thousand patents (from 1990-2007). That is to say, over 80% of public sector patents are assigned to CSIR, a network of publicly funded research laboratories. The large weighting of PROs,, compared to China and Mexico,, is explained by the long-term absence of universities in the national research system in India. As explained by Bassant and Chadran (2007), for many years, the PROs have been the main centers of research activity and universities have largely become teaching institutions. This pattern is changing, although the lack of industry orientation among academic institutions has constrained links between industry and academia.[67]

- Patenting by universities and PROs in South Africa has been relatively stable during the period 2001-2007. According to a recent study, despite the increase in the filing of provisional patent applications, the number of completed patent applications filed at the domestic patent office has remained fairly static (Sibanda, 2009). The University of Cape Town, the University of Stellenbosch, and the University of Witwatersrand lead the numbers in terms of provisional patent applications. In terms of complete applications North West University and University of Stellenbosch lead, followed by University of Pretoria and University of Cape Town.

3.3 PCT filings

Instead of choosing a national patent application at different country offices, applicants can use the PCT system as a channel for international patent protection. The PCT system, administered by WIPO and in operation since 1978, allows patent rights in different countries in the world to be obtained through a single patent filing (international phase). Applicants have the option to proceed to validation of the patent applications and obtain a grant at each national patent office (national phase). This strategy of internationalization is motivated by global market expectations but also as a means to impede patenting by other institutions and firms in foreign countries.

We used WIPO's Statistical database containing PCT data, and, and used the following procedures to classify PCT applicants into educational institutions and PROs. In the first step, we consolidated the names of non-individual applicants so that we have a standard name for each of them. Next, we used a list of keywords to identify educational institutions and PROs. In the final phase, we did manual checks andand made sure that all the applicants were classified correctly. When we had doubts about the classification, we performed a web-based search for additional information. We used a list of keywords containing the directories with the names of all universities and PROs in each country. One should note that we classified applicants according to their names only, without considering employment relationship.

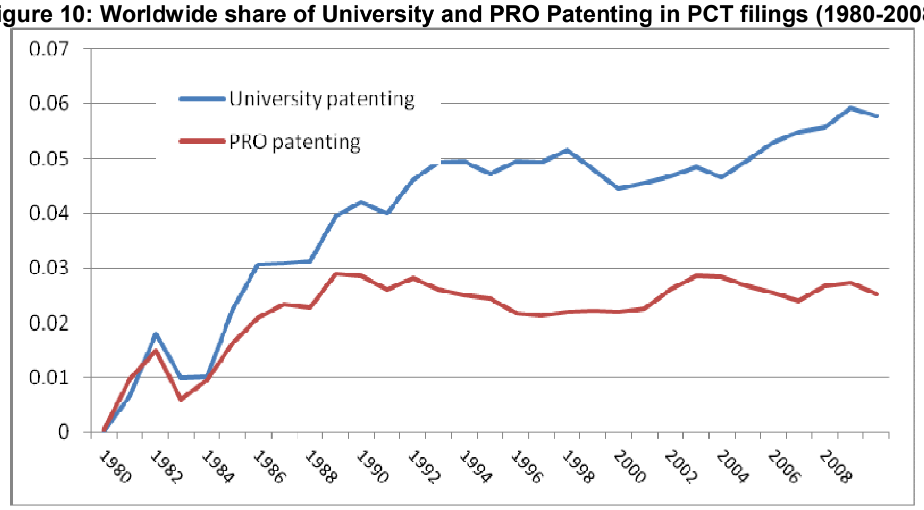
(Gupta, 2008).

[67] Most other government S&T departments and institutions increased their patenting activity particularly after 2000 (ibid). These include Defense Research and Development Organization, Department of Biotechnology, Department of Science and Technology, National Institute of Immunology, Sree Chitra Tirunal Institute for Medical Science & Technology, Jawaharlal Nehru Centre for Advanced Scientific Research, Centre for DNA Fingerprinting and Diagnostics, and the Department of Atomic Energy.

Therefore, if a person is identified as the applicant filing on behalf of an educational institution, that application would not be classified.

We compared our results with those produced by the algorithm developed by the Catholic University of Leuven (Van Looy *et al.,* 2006a) with PCT data from PATSTAT (version September 2010).[68] The latter relies on information contained in the applicant's name, and, with the help of a list of keywords, assigns applicants to an institutional category (universities, government, hospitals, business, private non-profit organizations and individuals). We used the complete lists of institutions (PROs and universities) in each country, thereby maximizing the identification of patentees and minimizing the problem of ambiguity in sector allocation. An additional difference is in the use of the applicants' name in each patent. We assigned the origin of an application based on the origin of the first applicant, whereas the classification of PCT data from PATSTAT with the Leuven method uses all applicants listed in each patent. We compared the two search methods for selected countries (having at least 4000 PCT filings over the period 1990-2010), and identified sources of divergence. In terms of university patenting, our scores are larger overall than the Leuven method but differences in terms of shares of total PCT filings per country origin are not significantly different. Scores between the two methods are pretty close for PROs, with the exception of four countries for which we have manually checked the list of patentees.

Figure 10: Worldwide share of University and PRO Patenting in PCT filings (1980-2008)



Source: WIPO Statistics Database.

Figure 10 displays the evolution of the worldwide share of university and PROs in total PCT filings published per publication year.[69] The PCT system began in 1979. Shortly after (in 1982), universities' share in world PCT filings overtook PROs. In 2008, universities accounted for 4% of all PCT applications published, whereas PRO accounted for 1.4%. Figure 11 and figure 12 displays the evolution of PCT filings originated from universities, and PRO applicants in middle- and high-income countries. As in the

[68] We are grateful to Helene Dernis from OECD (Directorate of Science, Technology and Industry) for providing us with the extraction of PCT data and the corresponding sector allocation per patent from PATSTAT, version September 2010.

[69] PCT counts for cross-country comparisons are not free of bias. PCT filings are options to present future applications at national country offices in different parts of the world, since the PCT procedure has two stages, international and national which implies the grant before national patent offices). Many applications do not proceed to the second stage (national or regional phase). Applicants can apply for international protection in case further market coverage is needed, although they may not be fully certain of the scope of protection needed. They may postpone decision of patentability at national offices, which is the most costly part of the process, eventually later in the process.

high-income countries, universities have taken over PROs in terms of the number of filings in middle-income countries. The shifting year point in PCT filings is 2005. By 2010, there were about 759 PCT filings from universities whereas the total number of filings reported by PROs was 500. However, about half of the expansion in university patenting in middle-income countries, originated from Chinese universities. In 2010, only 250 university PCT filings were registered in middle-income countries other than China, whereas China alone filed 526 PCT applications. A similar situation prevails in terms of PRO patenting in middle-income countries.

Figure 11: Patenting by research institutions in high-income countries (PCT filings), 1980-2010

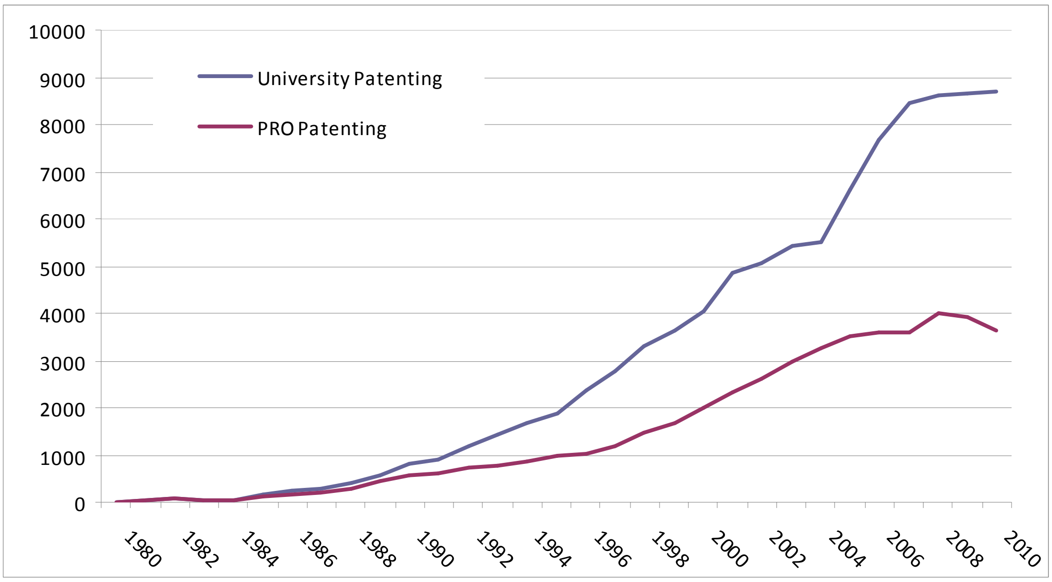
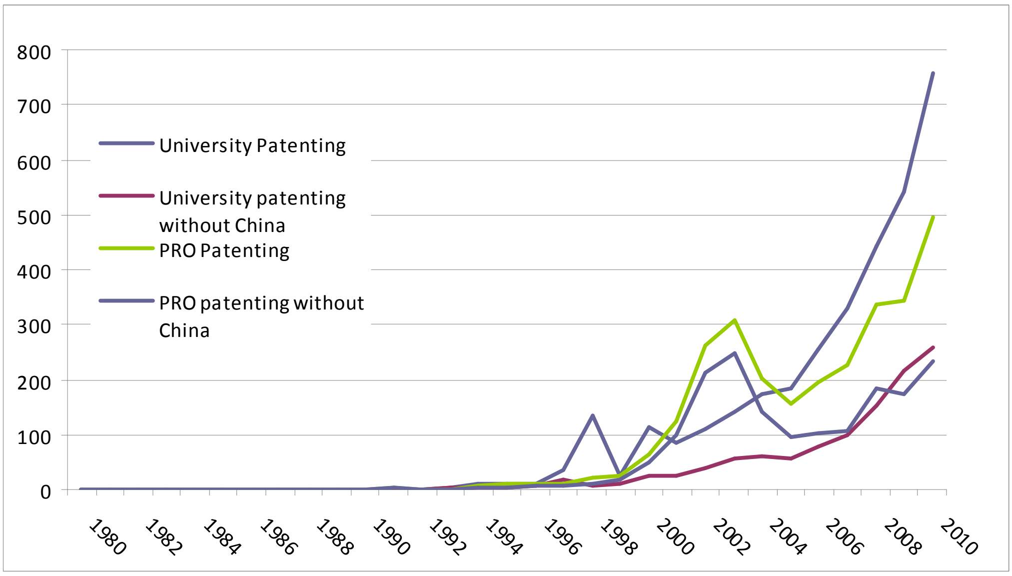


Figure 12: Patenting by research institutions in middle-income countries (PCT filings), 1980-2010

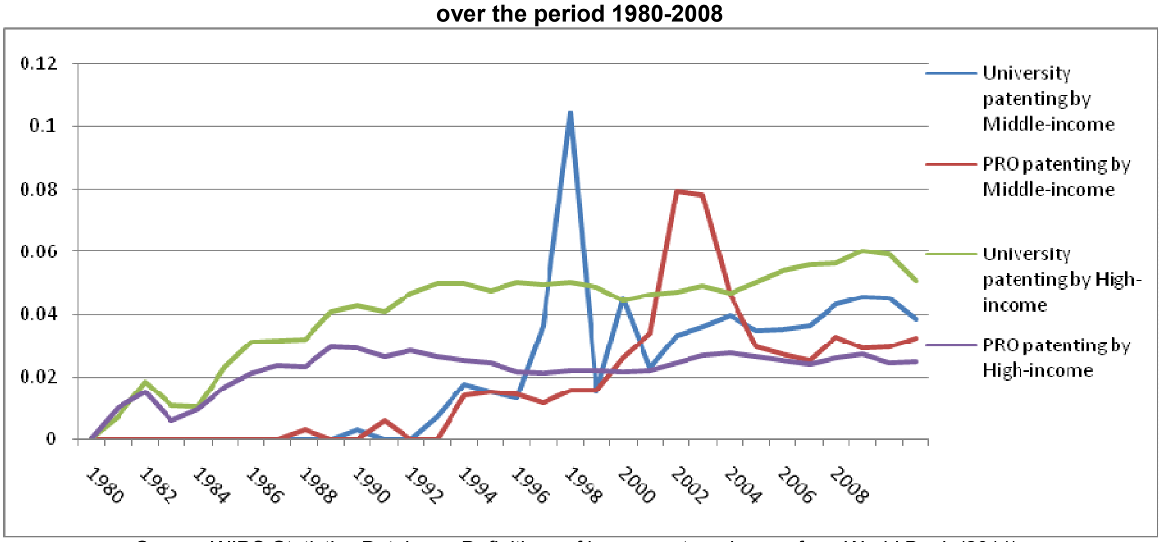


Source: WIPO Statistics Database.
Note: Definitions of High- and Middle-Income categories are from World Bank (2011).

Figure 13 displays the share of university and PRO patenting in total PCT filings per income group.[70] The universities' share of total PCT filings is larger in high-income countries during the period 1990-2010. In contrast, since 2000 the PRO share of total PCT filings from middle-income economies overtook the share reported in high-income countries. It should be noted that we reported the period 1990-2010 in order to have more stability in the patent series from developing countries. Before 1990, the number of PCT filings by residents in middle-income countries was very volatile. There is a steady growth in the two institutional sectors in middle-income countries. However, as stressed earlier, much of the increase in university patenting from these countries comes from China. University PCT patenting by other middle-income countries is more recent.

Figures 14 and 15 display the geographic distribution for middle-income countries for PCT patent filings published during the period 1980-2010. As previously mentioned, China is the leader in university patenting with 64% of PCT filings from universities (2,348 PCT filings) in this group of countries. It is followed by Brazil and India, with 8%, and 7%, respectively. Regarding the patents owned by PROs in middle-income countries, distribution is even more skewed towards China and India. PROs from China and India represent 78% of total patents by PROs originated from middle-income countries. They are followed by Malaysia with a share of 9% in total PCT filings by PROs originating from middle-income countries, and by South Africa and Brazil (4% each).

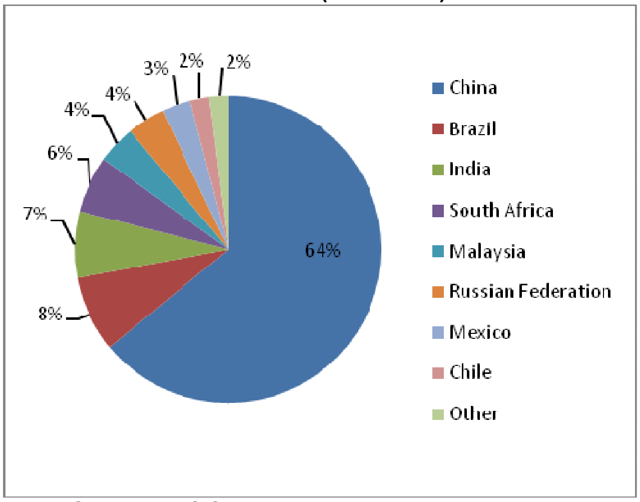
Figure 13: Shares of University and PRO patenting in total PCT filings per income group over the period 1980-2008



Source: WIPO Statistics Database. Definitions of income categories are from World Bank (2011).

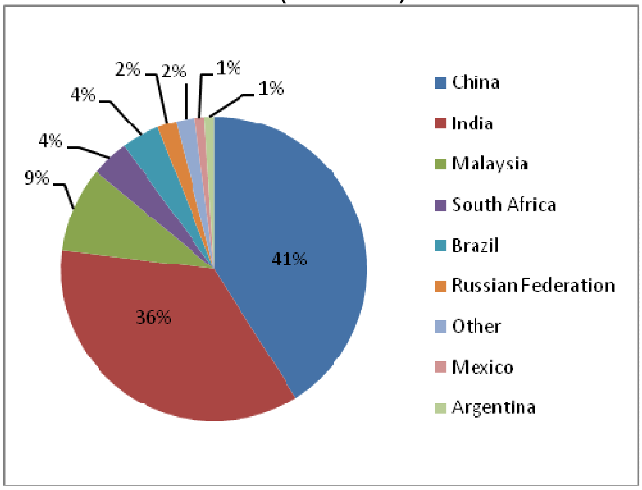
[70] Definition of income groups are given by World Bank, 2011.

Figure 14: University Patenting in Middle-Income countries (1980-2010)



Source: WIPO Statistics Database.

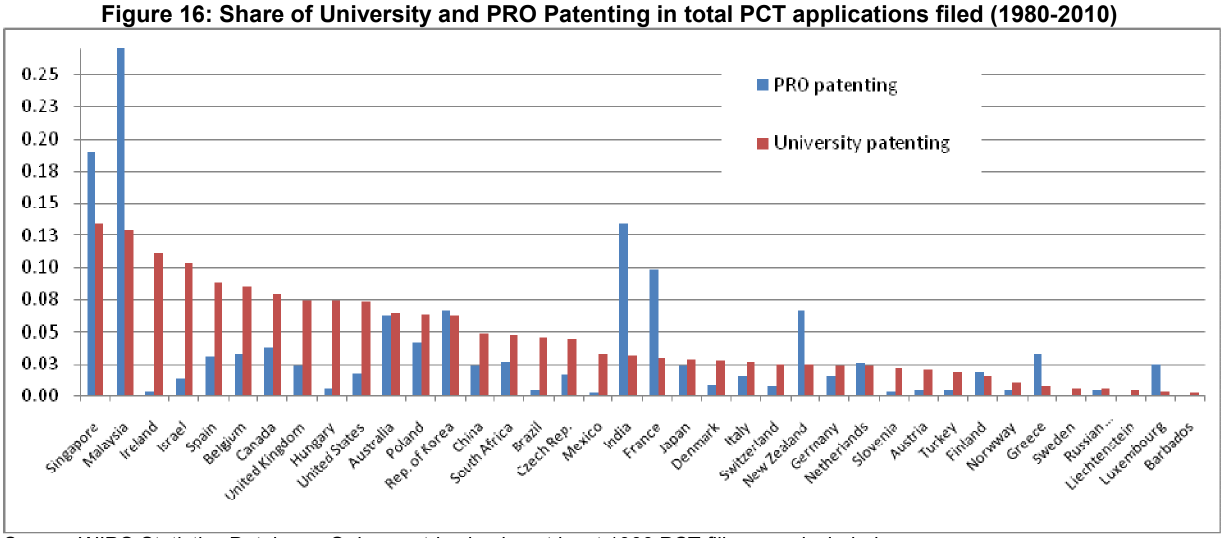
Figure 15: PRO Patenting in Middle-Income countries (1980-2010)



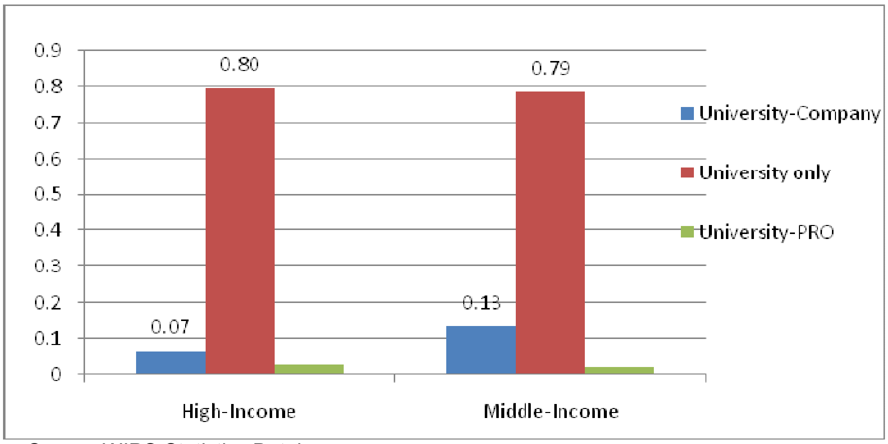
Source: WIPO Statistics Database.

Figure 16 reports the share of university and PRO patenting in total PCT filings published per country of origin (applicant). The highest rates of PCT university patenting are reported by Singapore (13%), Malaysia (13%), Ireland (11%) and Israel (10%). The countries with the highest participation of PROs in PCT patent filings are Malaysia (27%), Singapore (19%), India (14%) and France (10%). China and South Africa report the highest university rates within middle-income countries with 5% of PCT filings. Malaysia is at the top in terms of PRO patenting (27%), followed by India (13%) and Poland (4%).

Figure 16: Share of University and PRO Patenting in total PCT applications filed (1980-2010)



Source: WIPO Statistics Database. Only countries having at least 1000 PCT filings are included.



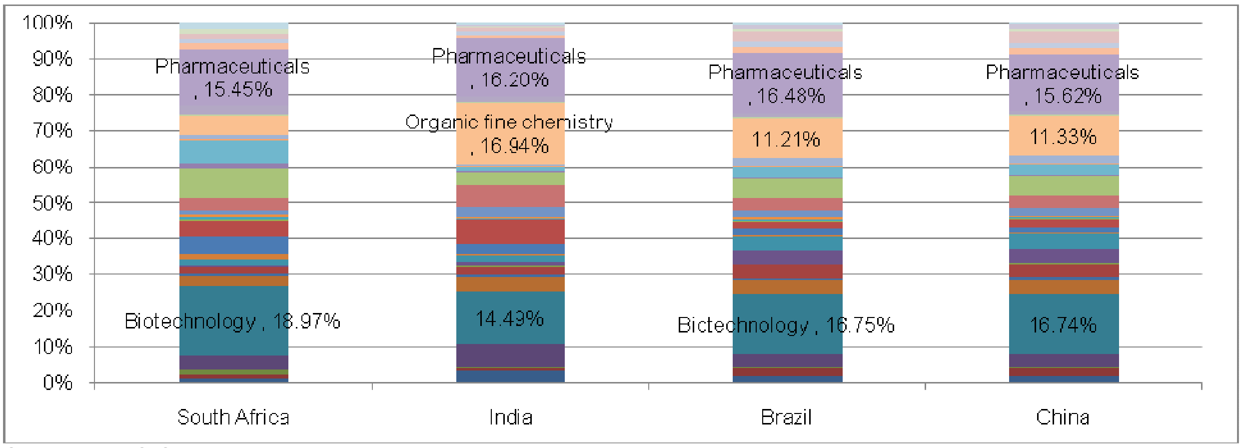
Source: WIPO Statistics Database.

Technology areas

Biotechnology, pharmaceuticals, measurement technologies and organic fine chemistry are the main technology areas in PCT patent filings by advanced economies and middle-income countries, such as Brazil, China, South Africa and India. Figures 18 and 19 display the allocation of PCT filings per technology field for a group of countries over the period 1980-2010. Patents in biotechnology represent 19% of PCT filings from South African scientific institutions, whereas in India, Brazil and China the average is 15.5%. Organic fine chemistry comes in third place in Brazil, China, and takes second place in India. In the United States, a quarter of PCT filings made by universities and PROs are in the field of biotechnology, however in the Republic of Korea and Germany this field only represents 10%. In the United States, the third technology field within PCT patents from universities and PROs is medical technologies (8% of PCT filings).

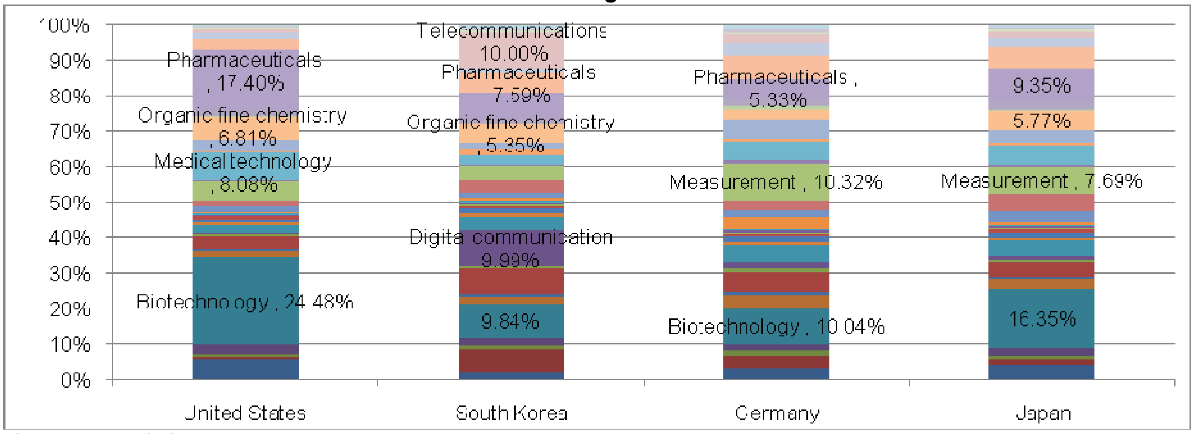
Biotechnology, digital telecommunications and telecommunications combined represent 30% of university and PROs' patents in Republic of Korea, each field with 10%. The specialization in ICT technologies reflects Republic of Korea's worldwide leadership in the development of ICT technologies as well as the dynamism of the information economy in this country (OECD, 2009b). Digital communications represent 10%. In Germany biotechnology and measurement technologies are the two leading technology fields with 10% of total PCT filings each, followed by pharmaceuticals, which are represented with 5% of PCT filings by scientific institutions.

Figure 18: Distribution of PCT patent applications (1980-2010) by universities and PROs across technology fields in selected Middle-Income countries



Source: WIPO Statistics Database.

Figure 19: Distribution of PCT patent applications (1980-2010) by universities and PROs across technology fields in selected High-Income countries



Source: WIPO Statistics Database.

IV. TECHNOLOGY COMMERCIALIZATION: CURRENT PRACTICES AND NEEDS

Technology transfer and commercialization of IP are at a premature stage in the majority of middle- and low-income countries. Statistical data are scarce, and, where available, they rarely uncover the diversity of technology transfer channels and are limited to specific case studies. This chapter discusses the current situation in terms of technology transfer at universities in a group of middle-income countries. We conducted interviews with managers at 8 TTOs. Based on the literature and the international experience, we inquired about university policy frameworks for technology transfer, what the incentives for researchers are, and the functions of the TTO, as well as the factors that influence patenting and the commercialization of patents. Best practices and obstacles to patenting and technology transfer are also identified.

4.1. IP and Technology Commercialization trends

There are a few studies that document the experience of universities in technology transfer activities in developing countries. Most of them focus on university patenting.[71] They all point to the nascent stage of IP and its commercialization. Recent evaluations of the state of university patenting and technology commercialization are available for China (Wu, 2010a), South Africa (Wolson, 2007a; 2007b; Sibanda, in WIPO 2009), and Latin America (PILA Network, 2009). There are some case studies in agriculture and health available for African countries. What emerges from these studies is that research universities and PROs in these countries are moving towards more institutionalized forms of technology creation and transfer of knowledge. This evolution is particularly important for university systems, as their role in research and innovation has just begun to be emphasized in many middle- and low-income countries. For the few countries for which evidence is available, it is noticeable that academic institutions are for the most part, new participants engaged in research and starting to collaborate with industry. It is perhaps too early to perceive a sizeable effect from recent policy reforms and institutional changes, notably the creation of TTOs at universities. Yet, as explained by Sibanda (2009) for South Africa and by Di Giorgio (2007) for Brazil, policy initiatives, while perhaps not yet fully deployed, are already contributing to a change in the culture at scientific institutions.

4.2 Analytical Framework

We relied on the analytical framework presented in the literature to design our questionnaire in investigating the state of patenting and technology transfer practices.[72] There are three main policy areas that frame IP commercialization at academic institutions. First, IP policies regarding ownership and commercialization at the institutional level are expected to provide certainty and clarity in the legal framework thereby reducing transaction costs -- asymmetry and agency problems - with private entities (Macho-Stadler *et al.,* 1996; Siegel *et al.,* 2007). Previous studies have underlined the role of university policies, and in particular the strategic approach towards the valorization of their research into university technology commercialization (Debackere and Veugelers, 2005). University policies regarding IP and technology commercialization include policies conveying norms on creation, registration and exploitation of IP rights (including policies addressing public good interests),[73] technology transfer policies, and rules

[71] Regarding PROs, there is wide literature with examples of successful technology transfer practices, in particular in agriculture and health, but unfortunately there is little documentation of intellectual property activities. State of IP management and technology transfer in PROs has been documented for Chile (Fernandez, 2007) and African countries (e.g. Boadi and Bokanga, 2007).

[72] The questionnaire used for interviews is reported in the Annex.

[73] IP policies concern the disclosure of discoveries, the patentability of inventions and register of other IP rights (industrial designs, trademarks, plant breeders rights, copyrights..), their management (i.e. promotion, commercialization and enforcement), among other regulations.

regarding conflicts of interest derived from researchers' involvement in spin-offs and external activities. IP policies may take part of a broader institutional policy framework on technology transfer activities. Having a technology transfer policy legitimizes the involvement of researchers in third mission activities. Universities having a clear mission of technology transfer with strong support and leadership by university directives are more able to build a friendly environment to academic innovation and entrepreneurship (Debackere and Veugelers, 2005). We inquired whether the university has in place a policy or guideline relative to the creation of IP, the development of R&D activities, and policy relative to technology transfer activities. We also asked whether the university has a policy regarding ownership of IP rights and how this policy works. Is it ownership with third parties possible (e.g. corporations and PROs)?

Second, the recognition of inventor participation in the technology transfer process is crucial. We asked managers whether their university provided royalty sharing with inventors and what other incentives were used to encourage researchers to participate in technology transfer. An appropriate policy framework should recognize the role of researchers and encourage them to contribute to IP creation and technology transfer activities. Incentives may include: inventor royalty compensation, awards, recognition in curricula (e.g. credits for tenure), and equity participation in spinoffs, among others. According to the international experience, royalty sharing and equity participation are proven policy mechanisms to encourage participation of researchers in patenting and commercialization of technology (Jensen and Thursby, 2001; Friedman and Silberman, 2003; Baldini *et al.,* 2006).

And third, organizational arrangements are needed to link with the external environment, coordinate and execute technology transfer activities. We asked managers about the characteristics of their TTOs: age, employees, number of IP professionals, budget and funding sources. We also asked about the functions that are implemented regarding IP management and commercialization such as identification of inventions, reception of disclosures, search of the state of the art, elaboration of the technical descriptive report, patenting and registration of IP, analysis of technical and market viability, search of partners and contract negotiation. By facilitating division of tasks across stake holders, TTOs take off the charge related to administration of IP and commercialization from researchers, and by building reputation and networking competences, they facilitate institutions' integration into technology markets (Link and Scott, 2005; Lockett and Wright, 2005; Rasmussen *et al.,* 2006; Siegel *et al.,* 2007). Several studies have emphasized the role of TTOs in licensing and startup formation (e.g. Siegel *et al.,* 2003; 2007; Caldera and Debande, 2010). In particular, the size and experience of the TTO as well as industry experience of staff have been found key factors in technology commercialization.

Based on the literature, we have designed a short survey to form the basis of our interviews including five main questions of research: i) country framework conditions, ii) intellectual property policy and policy incentives for researchers, iii) functions exercised by TTOs, iv) patenting and technology transfer indicators, and v) factors that affect patenting and obstacles to technology commercialization. Our questions of interest are the following:

- What is the current situation in terms of policy frameworks?
- Are universities adapting to new institutional contexts and adopting internal IP policies?
- How important are patents in technology commercialization?
- How are TTOs dealing with these new activities? Which factors most affect the patenting and technology commercialization?

Our questionnaire builds on recent surveys conducted in middle-income countries. We included several questions from the PILA Network survey for Latin American countries, *Gestion de la Propiedad Intelectual e Industrial en Instituciones de Educación Superior - Buenas Prácticas en Universidades de*

Latinoamérica y Europa and the survey study *Intellectual Property, Commercialization and Institutional Arrangements at South African Publicly Financed Research Institutions* (Sibanda in WIPO, 2009). We extend these studies and inquire about the factors that influence patenting and obstacles encountered in technology transfer activities. Our focus of interest is research universities. We look at some of the most important research universities in a group of 5 developing countries.

We interviewed 8 TTO managers at the following institutions: Instituto Tecnológico de Costa Rica (ITCR), Universidad de Costa Rica (UCR), Durban University of Technology (DUT) in South Africa, 3 universities in Mexico, CCADET-Universidad Nacional Autónoma de México (UNAM), National Institute of Astrophysics and Opto-Electronics (INAOE) Instituto Tecnológico y de Estudios Superiors de Monterrey (ITESM), Universidade Minas Gerais (UFMG) in Brazil and Universiti Teknologi MARA (UTM) in Malaysia..In addition, we received two questionnaires without having an interview from the Universiti Putra Malaysia (UPM) and the Universidade Estadual de Campinas (UNICAMP) in Brazil. All institutions are public with the exception of the ITESM in Mexico. All of these universities are engaged in research activities. Only the INAOE is a public research organization.

4.3 Findings

We summarize our main findings below. We describe and discuss the main features of IP practices and technology commercialization trends at the universities we surveyed. Our intention is to provide insights on the current situation in university IP policy, management and technology commercialization in a group of middle-income countries.[74] Tables 3-5 summarize the IP policies and TTOs' activities for the group of TTOs interviewed. The questionnaire used is reported in the Annex. Information from one university in Brazil was based exclusively on the questionnaire received and information gathered from the annual report and website.

National Preconditions for Technology Transfer: According to interviews and questionnaire received***,*** policy frameworks for technology transfer from academic research are pretty much similar within this group of countries. In Brazil, South Africa and Malaysia, according to interviewees, technology transfer is currently part of the national economic strategy and specific policy mechanisms have been launched for such purposes. In contrast, in Costa Rica, there is policy recognition of the importance of technology transfer for economic development, but specific incentives or instruments are not yet being deployed. In Mexico, the recent national innovation programs emphasize technology transfer as a policy milestone but its implementation is still at a nascent stage. Eight interviews stress that there is an adequate IP system in the country, with updated IP laws. The exception in this case is Malaysia; according to interviewees the update of the IP system is still in process. In all cases but Costa Rica, countries have a national IP policy framework governing IP ownership of publicly funded research results and legislations requiring sharing of revenues derived from IP with inventors.[75] Two managers (ITESM from Mexico and Minas Gerais from Brazil) emphasize that further progress is needed in terms of research competences as well as a better balance between applied and fundamental research with increased relevance to local economies.

In terms of availability of funding for technology transfer, the picture is mixed. In Costa Rica and Mexico, TTO officials declare that there are insufficient sources of funding that could enable the development of a

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[74] These experiences should be seen as examples of current practice and do not necessarily represent the general country situation. Conclusions should be read with care and should not be considered as fully conclusive for countries or regions under examination. Indicators of activity per university are reported for illustrative purposes and should be put into context.

[75] According to the two universities from Costa Rica, these two policy frameworks are lacking in the country, as well as a promotion of a culture of innovation. Interviewees consider that their universities have sufficient research capabilities to allow the development of new national technological competences.

technology transfer system, while in Brazil, South Africa, and Malaysia, this is not the case. In Malaysia, according to the UPM, there are sufficient sources of funding but most of them are public. In Brazil in particular, with the 2004 Innovation Law there has been strong governmental support and funding for the creation of Technological Innovation Nucleus (NIT) and technology transfer activities. Funding of research has constantly been increasing since the mid-1980s. Interviewees from Brazil, Malaysia and Mexico emphasize that there are strong scientific capabilities in the country but that there is no adequate university-industry collaboration, and that where it exists it is constrained to some specific sectors (Mexico and Brazil) and that they are slowly developing mostly with financial assistance from public funds (Malaysia). The University of Costa Rica declares that the development of industry-science linkages are in progress, while the ITCR explains that in general, there is a weak industry science linkage in the country. The Federal University of Minas Gerais shares the same opinion with respect to industry-science collaboration in Brazil. Among the main reasons for limited collaboration are the lack of demand by industry and limited absorption capacity (weak R&D capacity),, differences in culture (e.g. long term vs. short term) as well as difficulties to communicate between sectors.

University IP polices and ownership rules: In line with Sibanda (WIPO, 2009) and the PILA study (PILA, 2010), the universities we have interviewed have an IP policy in place or are in the process of drafting it (table 3). The UCR in Costa Rica and the INAOE in Mexico are in process of drafting their IP policies. The UNAM still lacks an internal IP policy but discussions are underway. At the UPM, both the R&D and IP policies need further fine tuning. The UNAM is the largest research institute in Mexico but its involvement in IP management and technology commercialization has been slow. Eight of ten universities have a technology transfer policy. UNAM is currently drafting itstechnology transfer policy while at the INAOE there is no draft available yet. Within the faculties (faculty of engineering and faculty of sciences) of UNAM however, almost every unit has its own department responsible for technology transfer, with their own technology transfer strategies, mostly defined on a case-by-case basis. At the UNAM, IP registration and contracting is managed at a central unit. At the UPM in Malaysia, the university has general guidelines for managing technology transfer activities but the structure of the organization handling these activities keeps evolving and so does the guidelines for practices, which in some cases are not clear.[76]

As regards the ***institutional ownership policy,*** with the exception of Malaysian and South African universities, ownership rights belong to the university but co-ownership with third parties is allowed. This is the case of the two universities from Brazil, the ITESM and INAOE from Mexico and the UCR from Costa Rica, which allow for joint ownership with firms or with public organizations in cases when the share of funding is substantial; when there is a meaningful intellectual contribution by partners, or simply under R&D contracting.[77] In some cases, policies even allow full transfer of ownership to partners.[78] In contrast, in Malaysia and South Africa, following the national policy framework, ownership over IP resulting from public funding goes exclusively to the university even in cases of industry collaboration. In Costa Rica, there is no national policy regarding ownership.. Universities are left to themselves to define their IP policy and strategy. At the UCR in Costa Rica, it is possible for inventors to retain ownership over research results. In South Africa however, co-ownership is not allowed according to new legislation even

[76] As explained by Sibanda (2009) and Wolson (2007b), not all South African universities have an IP policy in place. Research and contract agreements, however, often lay out the terms of use and ownership of results.

[77] This is in line with the PILA study, which reports that in universities in Argentina, Brazil, Chile and Peru, more than 50% of rights (with a maximum of 80% at UNICAMP) have shared ownership between university and partners involved in the research project.

[78] In Brazil, according to national law, ownership can be shared with inventors, but universities mostly opt to restrain this possibility (e.g. UNICAMP). This is also the case in Malaysia, where the national legislation allows such right but universities are not constrained to do that. The IP policy at the two universities interviewed stated that ownership rights belong exclusively to the institution.

in cases of collaboration and regardless of the level of funding contribution by firms.

Incentives for inventors to engage into patenting and technology transfer (see table 3): In all institutions interviewed, the IP policies consider revenue sharing with inventors. They also provide additional incentives such as recognition in curricula (IP criteria for career and research evaluation; all institutions but UNICAMP consider this incentive) and awards or economic prizes (ITM, DUT and UNICAMP). Equity participation in start-ups and temporary leave for start-up creation are less often used. Equity participation is only allowed at the two Malaysian universities and at the INAOE (Mexico), and only three institutions consider temporary leave (INAOE, UNICAMP (Brazil) and UTM (Malaysia)).At the UPM, equity in spinoff creation is given high importance. The TTOs assists in getting funds for the spinoff company and contributes with expertise. Participation across stakeholders is negotiable. It can take the form of 5-10% of university holdings; 10-40% participation by researchers and technical directors; and between 40-70% entrepreneur (external). According to the UPM, equity participation by researchers is a key element; it benchmarks success (researchers' involvement); provides security to the entrepreneur; sense of belonging and commitment by researchers and works as an assurance of quality control in the market.

The royalty sharing rule is higher in the two Malaysian universities and the DUT from South Africa (70-75%) as opposed to the Latin American universities (between 15 and 50%). The set of incentives differs across institutions, and even within countries. For instance, at the UPM Malaysia, IP is not seen as criteria for research evaluation at the UPM and temporary leave is not allowed, as opposed to the ITM where both incentives are in place. At the UNAM in Mexico, according to the Rules for Extraordinary Revenues for Researchers, scientists are entitled to a share of revenues resulting from technology services and commercialization: up to 40% of the direct cost of the project and up to 100% of the salary. Yet he university does not provide any other incentive for technology transfer (e.g. regulations do not allow for firm creation; equity participation; temporary leave for technology transfer activities are also not allowed). In Brazil, federal laws prohibit researchers at public institutions to get involved in the management of firms. However, as explained by interviewees, this is a career choice for researchers. At the UFMG, most researchers stay in their academic jobs and spin-offs are run by students who develop the firms or by surrogate entrepreneurs. Academic inventors keep contact through consulting.

Technology Transfer Offices: There is a high heterogeneity across offices in terms of resources and functions. The TTOs interviewed were less than 8 years old on average (see table 4). The oldest is the TTO of the UFMG from Brazil, which was created in 1996. It is worth mentioning that the University of Costa Rica created a technology transfer unit in 1990, but it was transformed into PROINOVA in 2005 with an institutional decree that expanded its mission and activities. The number of employees and budget vary widely across the units interviewed. Offices have between one and 16 employees. The Innovation Agency of UNICAMP, referred to as INOVA, is outside this bracket with 37 employees and it is probably the office with most experience in IP and industry-science links. In general, offices have one IP specialist. The exception is the Instituto Tecnológico de Costa Rica, which has a legal office which centrally manages IP protection. A similar situation exists at the UNAM in Mexico (the largest university in this country), where faculties have their own department for technology transfer but IP management, as well as other legal activities, is processed at a central unit (IP Office). The CCADET from the UNAM has only one specialist in IP but the central IP Office of the university has more than five professionals. IP register and commercialization are managed both between the central and the faculty TTO.

Functions of TTOs: TTOs interviewed are multi-purpose units dealing with different activities related to technology transfer in its various guises. They also deal with accessing funding for research and education, research contracting, developing and managing liaison with industry, among others. Some

TTOs are involved in regional economic programs and associated with technology parks or clusters, and some of them have incubator programs hosted at their own institutions (e.g. ITCR, in Costa Rica, ITESM Monterrey in Mexico and UNICAMP in Brazil). However, expertise and infrastructure are still weak. Almost all TTOs say they conduct the following activities: assessment of patentability, search on the state of the art, management of disclosure of inventions, and patenting procedures (at national offices basically).

Table 3: Policy practices and TTO activities: examples from middle-income countries

Institution	Mexico			Brazil		Costa Rica		Malaysia		South Africa
	CCDAT UNAM	INAOE	ITESM	UFMG	UNICAMP	ITCR	UCR	UTM	UPM	DUT
Public/Private	Public	Public	Private	Public	Public	Public	Public	Public	Public	Public
Researchers	100	415	253	2654	1733	159	1000	N.R.	>2000	N.R.
Policy/guidelines										
IP policy	I.P.	I.P.	YES	YES	YES	YES	I.P.	YES	YES	YES
R&D policy	YES	NO	YES	NO	YES	YES	YES	YES	YES	YES
Technology transfer policy	I.P.	NO	YES	YES	YES	YES	YES	YES	YES	YES
IP ownership	YES	YES	YES	YES	YES	YES	I.P.	YES	YES	YES
Institution	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Institution with others	NO	YES	YES	YES	YES	NO	YES	NO	NO	NO
Researchers	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO
Policy of revenue sharing with inventors	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Share for inventors	up to 40%	*	30%	33%	33%	50%	*	70%	75%	70%
Other incentives for researchers:										
Awards or prizes	NO	YES	YES	YES	YES	NO	NO	YES	YES	YES
IP criteria for evaluation	YES	YES	YES	YES	NO	YES	YES	YES	NO	YES
Economic incentives for registration of IP	NO	NO	YES	YES	NO	NO	YES	NO	YES	YES
Equity participation	NO	YES	NO	NO	NO	NO	NO	YES	YES	NO
Temporary leave	NO	YES	NO	NO	YES	NO	NO	YES	NO	NO

Note (*): INAOE: only to overhead (40%). UCR: 35% (<200); 25 (<500); 15% (>500). I.P.: In process. N.R: not reported.

Source: Author based on interviews and questionnaires received.

They frequently outsource (or work in partnership with contracted IP firms or experts) the following activities: i) description of the technical report, ii) patenting at national and international offices, even registration of other IP. Four TTOs completely delegate international registration of IP to specialized firms or experts. Exploitation of patents through licensing and start-ups is minimal and limited to few universities.

Table 4: TTO's personnel and activities: TTOs examples

Institution	**CCDAT**	**INAOE**	**ITESM**	**UFMG**	**UNICAMP**	**ITCR**	**UCR**	**UTM**	**UPM**	**DUT**
Personnel	2	1	7	35	37	8	12	15	28	6
IP specialists	1	1	5	0	6	3	10	1	N.R.	1
Year of creation	2007	I.P.	2005	1996	2003	2006	2005	2007	2006	2008
Budget 2009 (USD)	3000	20 000	100 000	N.R.	N.R.	11 107	98 057	N.R.	N.R.	N.R.
Activities by TTO										
Identification of inventions	1	1	1	1	1	1	1	1	1	1
Reception of disclosures /communications	1	1	1	1	1	1	1	1	1	1
Search of the state of the art	1	1	1	1	1	1	1	2	1	2
Elaboration of the technical report	1	1	1	1	1 and 2	1 and 2	1 and 2	1 and 2	N.R.	2
National IP registration	1 and 2	2	1	1	1 and 2	1	1 and 2	2	N.R.	2
International IP registration	1 and 2	2	1	2	1 and 2	1	1 and 2	2	1	2
Analysis of technical /market viability	1	1	1	1	1 and 2	1	1 and 2	2	1 (a little)	1
Promotion and search for partners	1	1	1	1	1	1	1	1 and 2	1 (not enough)	1
Contract negotiation	1	1 and 2	1	1	1	1	1	1	1	1

Source: Interviews and questionnaires. 1: function conducted internally; 2: function conducted externally (outsourced). I.P.: In process. N.R.: Not reported.

Training and technology transfer skills. Several TTOs interviewed provide training courses to researchers on the use, drafting and registration of IP and their importance for technology transfer. In several countries, national initiatives have been launched to improve technology transfer skills at the TTO. In South Africa, the *Southern African Research and Innovation Managers Association* was created in 2002. It aims to support the professional development and increase the capacity of those involved in managing research and/or innovation. Through training and specialized courses, it promotes the use of best practices in the management, administration and support of research and innovation. In Brazil, the government has commissioned INOVA from UNICAMP to assist in the formation of skills at other TTOs in the country. Training courses are currently taking place. At the ITESM in Mexico, there are specific measures being taken for the development of entrepreneurship skills and the creation of academic high tech firms. The *Incubation Cells Program* aims at providing entrepreneurship skills to Ph.D. students. Students are incorporated into a *Catedras de Investigación* (Research Chairs), where, with the help of supervisors, they define an incubation project to establish a new technology-based firm. Currently, there are 25 technology-based incubation cells at the Monterrey Campus.

Regulatory constraints: Interviewees from Mexico and Costa Rica stressed that normative regulations governing the functioning of public organizations constrain the development of technology commercialization and academic entrepreneurship. At the ITCR, the normative frameworks state that the university must keep 50% of equity in spinout companies. Furthermore, the current legislation does not allow researchers to be involved in start-up creation and have equity participation. They must quit the public function and conform to the exclusive employment rule. There is currently a law under review at the Parliament concerning these restrictions. A similar situation prevails in Mexico, where regulations regarding public servants do not allow their participation in corporate activities. In Costa Rica, there is a heated national debate about the corporatization of universities and rent generation, and a reticence from high-level jurisdictional offices to change policy frameworks. To overcome such barriers, the ITCR manages its technology transfer activities (research development and contracting, technology extension services and other forms of external liaison) with the industrial sector through the FUNDATEC Foundation. An additional handicap discouraging patenting is the delay of patent procedures. Universities from Costa Rica and Brazil stressed the difficulties experienced with IP registration and the long time it takes to get a patent grant. It takes about 8-10 years to get a patent granted in Brazil and Costa Rica. By contrast, less than a year is needed at the national IP office in South Africa. To deal with these handicaps, interviewees from Costa Rica stressed that secrecy and confidentiality agreements are often used in technology transfer agreements.

Table 5: Intellectual Property and Technology Transfer Indicators (total historic)

Institution	CCADT	INAOE	ITESM	UFMG	UNICAMP	ITCR	UPM	UCR
Researchers	100	415	253	2654	1733	159	2000	1000
National patent applications	3	6	202	368	554[a]	4	315	7
National patent grants	1	3	13	14	71[b]	2	52	1
Number of international patent applications	2	5	33	37	54[c]	0	65	4
Number of patents being licensed	0	1	13	27	68 [d]	0	N.R.	1
Number of startups created/spin outs	0	1	30[f]	54	0	2	7	1
Number of patent licensing contracts	0	1	5	27	54[d]	2	20	10
Number of technology contracts	13	25		7	N.R.	150	N.R.	N.R.
Patent exploitation rate	N.R.	0%		2%	12%	2%	N. R.	1%
Trademarks	10	1		57	N.R.	7	45	170
Utility models	13	0		25	N.R.	0	1	0
Plant varieties	na	na		na	N.R.	0	N.R.	0
Industrial designs	N.R.	0		11	N.R.	0	60	0

Source: Interviews and questionnaire. a: Period 2000-10;. b: 1999-2010; c: 2001-2010 (PCT application); d: 2000-10. na: not applicable. f: During 2009 and 2010. N.R.: Nor reported.

In terms of patenting and commercialization, the indicators show a high heterogeneity in patenting and technology commercialization across institutions. The most active, and probably with the largest experience in technology transfer within this group of universities, are UNICAMP and UFMG, from Brazil and the UPM from Malaysia. These universities have a record of more than 300 national patent applications and more than 30 international patent filings. The ITESM is remarkably active in startup firm creation, compared to its peers and taking into consideration its size in terms of researchers. We should note that the figures for those universities reporting smaller numbers in patents can substantially change if we take into consideration the most recent data. For instance, the UCR, although only reports 7 national applications until 2010; five applications have been filed during the first semester of 2011. In terms of licensing, we should also consider that the universities are also involved in other forms of commercialization of IP, which are in many cases, more intensive than patent licensing. For instance, the UCR is involved in licensing of trade secrets, copyrights and trademarks.

Factors affecting patenting. The most important factors affecting patenting are: i) awareness of the benefits of IP (patents) among researchers, ii) linkages with industry (to identify technology demands), and iii) having inventions with good commercial potential. Interviewees agree that relationships with firms are yet to be developed and/or strengthened. In most cases, the promotion of intellectual property and the creation of TTOs have emerged in university contexts where linkages with firms have historically been scarce or non-existent. As declared by several interviewees, research is often disconnected from industry needs. Exceptions are the ITCR and UNICAMP, where there is a long tradition of university-firm collaboration. With the exception of the two institutions from Costa Rica, the lack of patent information or search skills (e.g. analysis of patent databases), and the existence of an IP policy at the institution are factors considered as having less importance than the factors above mentioned.

Finance available for patenting and human resources to screen inventions are deemed important in half of institutions. The existence of public policy programs supporting full or partial costs of patent applications explain the reasons for the limited importance of finance for patenting in countries like Brazil and Malaysia. Furthermore, at UNICAMP, international patent applications are afforded by partners (firms), identified ex-ante as licensees. At the UFMG, technologies are evaluated with respect to their market potential. If there are market opportunities, inventions are patented, otherwise, if there is no market candidate there is no patenting; the university publishes results and anyone can apply for patent protection. In general though, patentability assessments are rare and there is no formal standard procedure (e.g. committee of evaluation) to assess whether an invention deserves patent protection or not.

Box 3: Integrating conditions for university technology transfer: the case of INOVA at University of Campinas in Brazil

The case of University of Campinas (UNICAMP), a university publicly funded by the state of São Paulo, is unique among universities in Latin America in patenting and technology transfer activities. With more than 200 technology licensing agreements signed during the period 2000-2010, UNICAMP is the biggest university technology transfer provider in Brazil and Latin America. Several factors have contributed to such dynamism and culture of innovation:

- UNICAMP is a higher education institution with strong component of graduate and post-graduate researchers (half of students are graduate students). It represents 17%of national research and 10% of PhDs in the country (Reydon, 2009), and is the university with the highest number of top rated PhD and MSc programs in Brazil (ibid).

- For research activities, UNICAMP effectively manages different sources of funding including federal and regional sources. A key element of success has been the creation of INOVA, the Innovation Agency of UNICAMP, in 2003. INOVA is a multi-task agency charged with encouraging, promoting, and facilitating the relationship between the university and the market to encourage interdisciplinary research on various matters, education and knowledge development.

- Technology developments at UNICAMP are driven by industry needs (Di Georgio, 2007). Instead of selecting UNICAMP's technologies and offering them to the market, INOVA first identifies the market demand, and, in response, looks to the university for the solutions available. Another factor that contributes to INOVA's success is the professional staff involved in technology transfer. The team includes personnel with business skills and industry experience. As UNICAMP has multidisciplinary competence, agreements are made with private companies and with the government, in many industry sectors.

- INOVA makes use of public policies both at regional and national level in their deployment of technology transfer strategies. The university makes use of government incentives for innovation, such as tax benefits for technology companies,, subsidies of researchers' wages in firms (50% of the salary is sponsored by the government), and other support policies in priority sectors (information technology, energy, semiconductors, biotechnology and pharmaceuticals).

- INOVA manages several collaborative programs at the different stages of technology transfer cycle: *Strategic Partnership Program, Continued Education & Training Program, a Science Park Program, Incentive Program to Technological-based start-up companies*, and *Intellectual Property Program* (Registration and Licensing).

Sources: INOVA (2010) and website, Reydon (2009) and Di Georgio (2007).

Obstacles to commercialization of patents. According to interviewees, technology commercialization from academia encounters several obstacles in their countries but conditions are improving. Research capabilities, absorption capabilities by firms, which are weak in most cases, the lack of trust between science and industry partners, the lack of finance for start-ups (in most countries except for Brazil), the need for post-licensing support, the stage of development of inventions (too embryonic), and linkages with industry, are all deemed relevant factors affecting the commercialization of patents. With the exception of the two institutions from Costa Rica, most cases declare that missing IP policy is not an obstacle to technology commercialization, and there are no constraining government regulations. Most countries currently have wide technology transfer programs relating institutions with clusters, incubators and economic development plans. The lack of commercialization is not associated with weak relevance of research for local markets (inventions targeting Northern markets), and, in most cases, weak protection of patent rights is not a problem relevant to commercialization of technology.

4.4. Elements of Success and Challenges

The TTOs analyzed here differ widely in terms of resources, staff, financial and operative empowerment, as well as in the nature of technology transfer activities they conduct. There are a number of points which TTO officials agree could improve the effectiveness of technology transfer systems. We summarize them as follows:

- The development of industry-science linkages is crucial. That requires the improvement of communication and networking with industry, expanding collaboration in research and technical assistance, personnel exchange, among others. Improving closeness with firms would allow better targeting of research needs and strike a better balance between applied and fundamental research.

- As explained by several interviewees, cultural differences are a major barrier between universities and firms. Differences exist with respect to the speed of projects (it requires time to generate technological solutions while the private sector demands fast responses). Furthermore, private firms often complain about science's lack of adaptability to changing industry requirements. As such, there is a need to improve the innovation culture and industry-linking skills in academia. Raising awareness about the importance of technology transfer at scientific institutions remains a major task. This is facilitated by the definition of clear missions and mandates at universities (and PROs), leadership by directorates (and presidencies), and the recognition of technology transfer activities in careers. Formation of entrepreneurship skills is also helpful. At the ITESM in Mexico and INOVA in Brazil these elements have played a major role.

- A crucial element to improve commercialization skills at TTOs consists of having the right combination of competences at the TTOs. At INOVA, professional staff is made up of IP professionals, staff with S&T background and personnel with business and industry experience.
It is also important to maintain the commitment to technology transfer over time and, to this end, ensuring continuity of research, and researchers' dedication to technology transfer needs over the existence of licensing contracts. Inter-generational knowledge collaboration among researchers themselves, both juniors and seniors, is therefore important to ensure the continuation of technological assistance to licensor firms.

The most experienced TTOs (in Brazil) face the challenge of retaining personnel. Indeed, TTOs constitute a new source of employment for graduates and training institutions providing new skills. In fact, new staff members often see the TTO as a training school and move quickly to industry. Given the increasing demand for IP management and technology transfer skills in the country, those with technology transfer experience are highly sought after by the private sector. Providing attractive wages and career development is necessary for TTOs to retain talented people, and this needs to be considered in the design of technology transfer policies. TTOs are charged with the promotion and coordination of IP and technology transfer activities. About half of them conduct other important tasks including leveraging of funds, as well as cluster, incubation and other regional economic programs. It is clear that such a broad mission requires meaningful economic and human resources to be deployed. Yet most TTOs interviewed here are highly under-resourced in terms of human capital and infrastructure. In addition, there is a learning process for both TTOs and industry to get involved and familiarized with new IP strategies; and as shown by the international evidence, it takes time before a TTO can generate economic returns and break even with costs.

Box 4: Industry linkages and Entrepreneurship Skills Formation: the case of Monterrey Institute of Technology and Higher Studies (ITESM)

The Monterrey Institute of Technology and Higher Studies (ITESM) is a private national multi-campus university in Mexico with headquarters in Monterrey. The university was created under private initiative in northern Mexico with the aim of creating human resources with the highest standards of education, and the provision of engineering and technology skills to regional industries. The recent patent activity of the ITESM places it among the top three universities patenting in Mexico. In 2007 the institution was awarded with the National Prize of Technology. Among the most salient features of the Institute are:

- Industry collaboration has been at the heart of research activities and infrastructure such as the creation of the Femsa Biotechnology Center and the Motorola Research and Development Center on Home & Networks Mobility. With a new institutional mission in 2005 underscoring research as one of the Institute's priorities, new research infrastructure has been created with support from public and private institutions.

- Within Latin America, the ITESM, is recognized for its early focus on developing professionals with entrepreneurial skills and culture (World Bank, 2010). The first initiatives to teach entrepreneurship date back to 1978 and these gradually evolved into the *Programa Emprendedor*, jointly designed between academics and the private sectors. Today, all its degrees include entrepreneurial courses as an integral part of curricula. This vision is also being applied in the formation of PhDs. The *Incubation Cells Program* aims to provide entrepreneurship skills to Ph.D. students. Students are incorporated to a *Catedras de Investigación*, where, with the help of supervisors, they define an incubation project to establish a new technology-based firm. Currently, there are 25 technology-based incubation cells at the Monterrey Campus.

- During the period 2003-2010, 158 domestic patent filings were made, 13 patents have been granted, 26 spin-offs were created, 15 trademarks registered and 13 patent licensing agreements were signed. New technologies developed are in the field of biotechnology, health, information technologies, renewable energies, manufacturing systems and design.

- With the aim of better impacting regional economies, the ITESM is involved in the set-up of science and technology parks at several of its campuses. Four development models have been introduced according to the contextual characteristics of Mexican regions. The CIT² (Centre for Innovation and Technology Transfer) is a technology park that opened in April 2005 in Monterrey, and has been growing with around 22 technology-based local and global companies added to the regional economic landscape.

Source: Based on interviews (February 2010) with representatives of TTO, Molina *et al.,* (2011), ITESM website and Wikipedia.

4.5 Discussion

Based on the information gathered for a group of middle-income countries (India, China, India and a group of Latin American countries) and the interviews we conducted, we identify the following general trends. Research universities are developing institutional frameworks and arrangements for patenting and technology transfer. However, the university capacity to patent, and the infrastructure for technology transfer differ widely across and within countries. Within each country studied, the bulk of patenting and technology transfer is concentrated in very few institutions.

There are several difficulties that universities encounter in the implementation of new policy programs promoting university patenting and patent commercialization. Universities, and often PROs,, do not have operative guidelines about disclosure and patenting.. And there is limited awareness by researchers of the new policy frameworks and benefits derived from IP activities. In most countries for which testimonies and evidence are available the three major constraints are: i) the persistence of weak linkages with industry inherited from long standing disconnection from firms; ii) weak communication mechanisms and networking skills, and iii) the lack of specialized staff in technology transfer (IP and technology managers). The information gathered suggests that patents have a minor role in technology transfer transactions. Evidence for Latin America suggests that universities give special attention to trademarks, copyright and industrial design (PILA Network, 2009). In some countries where ownership of IP is unclear or policy frameworks are weak, secrets and confidentiality agreements are widely used in technology transfer agreements. Firm creation is flourishing through incubation programs in countries like India and Brazil, even though most of this activity is weakly related to patents.

In some countries, institutional constraints – such as employment rules for civil servants and bans on creating private organizations at public universities, or joint-ventures with firms, limit academic entrepreneurship. Complementary factors needed for developing an efficient technology transfer system are currently being built and with few exceptions, they are mostly at initial stages, notably in terms of innovation capabilities of industries, availability of funding (venture capital and specialized investment funds; e.g. nanotechnology and biotechnology), and technology transfer skills (through the creation of national training programs and organizations). Public support by governments to improve skills and infrastructure, are fundamental to make TTOs more effective intermediaries.

V. IMPLICATIONS OF UNIVERSITY PATENTING AND POLICY LESSONS

In this section, we discuss the main policy implications derived from the promotion of university patenting as instrument to foster technology transfer. We review policy lessons from advanced countries and then summarize the most important policy issues that should be taken into account when promoting university patenting in middle- and low-income countries. We also stress policy challenges that need to be tackled in the construction of effective technology transfer systems.

5.1 Policy recommendations

From the review previously presented and experiences discussed throughout this paper, several policy issues are derived. Patenting and licensing can open new opportunities for technology transfer and commercialization at research institutions. However, the design and implementation of IP policies requires due diligence to minimize undesired effects on traditional missions of universities and research.
The discussion shows that the use of patenting to increase technology transfer is not an easy task and its importance may differ across countries according to their level of development and technology transfer needs. While patents certainly open up a new era of opportunities for industry development, their implementation requires careful design and complementary conditions are needed for technology transfer to flourish. The latter requires a comprehensive agenda of public policy targeting the different elements to build an effective technology transfer system that spans multiple channels of interaction between industry and science, and not only patents.

Furthermore, the international experience shows that the use of patents for technology transfer is a costly process that requires specialized skills and institutional arrangements (e.g. TTOs) needing financial and institutional support for their sustainability and performance. As explained in previous sections, the role that university patenting may play in spurring technology transfer and foregoing industry-science linkages are affected by numerous factors, among them are the underlying structures and governance of research and higher education systems, the technological needs of firms, the research capabilities of institutions, the policy and regulatory framework (IP protection and business creation), and adequate infrastructure and funding for technology transfer activities and spinoff creation. Developing an effective technology transfer system also requires a sound and proactive IP management, which helps to make partnerships more effective and allows technologies to be transferred not just in one direction but in more complex and valuable ways, to benefit society (Krattiger *et al.,* 2007).

We summarize fundamental issues to consider in the design of technology transfer policies and the use of patenting for fostering technology transfer from research institutions in middle- and low-income countries next.

5.2 Governance of research and university systems

University and research systems: As explained by Mowery (2005), Mowery and Sampat (2008) and OECD (2003), broader restructuring of university systems is needed to encourage collaboration with industry and facilitate the development of knowledge transfer activities. Autonomy of universities in terms of recruiting, financial management, and ability to create economic corporations is necessary to facilitate technology commercialization and academic entrepreneurship. Research systems in low- and middle-income countries also face the challenge to improve research infrastructure and the number of researchers through increased funding and more attractive wages to retain talented scientists (Maculan, and Carvalho de Mello, 2009). In addition, the modernization of research systems to make them more competitive requires the adoption of funding schemes that will encourage inter-institutional competition and the use of performance evaluation. Many middle-income countries have recently progressed in this sense.

5.3 Spanning multiple technology transfer channels

Knowledge transfer channels: The evidence available shows that knowledge transfer from science to industry occurs through various channels, of which informal means -- publications, conferences and personal contacts - are often more highly valued by firms.[79] Patents and licensing are a small fraction of the ways academic knowledge diffuses from the university to industry and society. Furthermore, as explained by Covylas *et al* (2002) and Shane (2004), patent licensing of university inventions is relevant to innovation commercialization in specific technology and science contexts (e.g. life sciences).
These findings stress the importance of diversity in the promotion of technology transfer policies and suggest the adoption of a more holistic approach when using patents as instruments for technology transfer. It is also important to keep in mind that needs of firms in terms of knowledge transfer vary across contexts, according to their S&T capabilities and the type of knowledge generated at institutions. For firms in low-income countries, well-trained human resources and technology services are probably the most important means of development and catching-up (Mazzoleni and Nelson, 2007). Therefore, traditional forms of technology transfer should preserve special attention in technology transfer policies.

Importance of industry-science collaboration: As explained by Mowery (2005) for the US case or Debackere and Veugelers (2005) for the European case, industry-science collaboration is a major contextual element in the development of technology commercialization. The implications for middle- and low-income countries are clear. It is important to promote industry-science collaboration at large. In many cases, patent-based commercialization is often the result of longstanding industry-firm interactions. Furthermore, Covylas *et al*. (2002) note that patent licensing is usually the result of a bottom up activity of informal interaction.[80] It often occurs in a concentrated number of industries those with which the universities have built up tacit relations and have cumulated experience in collaboration with industry (Wright *et al.,* 2004). However, an over-emphasis on patents may inhibit the development of research collaborations since attention may be too focused on ownership of the IP (Thursby and Thursby, 2007; Valentin and Jensen, 2007). In attracting firms when commercializing technology, universities may need to consider carefully and realistically the commercial value of their research and inventions and consider cases where ownership of IP may be co-owned or fully owned by firms.

5.4 The design of smart IP policies

Making use of intellectual property: The relevance and use of patents to enhance economic impact of science may differ across countries according to their level of development. Technology transfer requires as major pre-conditions a critical mass of research and high quality of science, an academic culture embracing entrepreneurship as well as specific institutional capabilities and finance (Siegel *et al.,* 2007; Wright *et al.,* 2008; O'Shea *et al.,* 2010; 2008).[81] These elements are in the process of being constructed

[79] Recent evidence from Argentina (Arza and Vazquez, 2010), Brazil (Rapini *et al,* 2006; Costa Povoa and Rapini, 2010), Mexico (Dutrenit *et al,* 2010) and Thailand (Intarakumnerd *et al*, 2002)) shows that publication, conferences, personal mobility and training are most often used channels for knowledge transfer and they are the ones that impact industrial innovation the most.

[80] Colyvas *et al.* (2002) in an in-depth study of six inventions found the transfer of technology from universities originates through informal networks that exist between academics and industrial corporations and not through the formal channels of the technology transfer office. Accordingly, formal technology transfer of explicit, codified knowledge is a consequence of that informal network of relationships.

[81] Wright *et al* (2008) use survey and interview data relating to mid-range universities in mid-range environments in the United Kingdom, Belgium, Germany and Sweden. Their findings suggest that mid-range universities primarily

in most middle- and low-income countries. Those countries that are more scientifically advanced are starting to reap the benefits of long term investments in education and research investment. They may find patents attractive to enhance commercialization of new technology created at research institutions and firm creation. Countries less economically advanced, with limited research capabilities at universities and PROs, may also find IP helpful in international collaboration agreements, especially to access collective intellectual commons for research and to access foreign technology, as well as to protect public nature of technology for humanitarian and social purposes. IP therefore may be instrumental in promoting access and diffusion of technologies. Middle-income countries may want to emphasize this dual use of IP, not only for technology and firm development but also to ensure freedom to operate and maximize control and access to technologies with high humanitarian impact, and contribute therefore to social development.

Minimizing undesired effects and ensuring a balance across missions: As previously exposed, a major challenge when dealing with university patenting is to design the appropriate policy framework to effectively encourage technology transfer while preserving fundamental goals in research and education. University policies are fundamental to avoid undesired effects on research and collaboration and traditional missions of universities.[82] Directives by national authorities can be given in national codes of conduct or through specific regulations in technology transfer laws. The ultimate goal of IP at research institutions should be dissemination of university technology for economic development and the public good.

The evidence previously discussed for high-income countries suggests that negative effects on science may arise, although effects reported are rather modest, and therefore a careful design of IP policies is needed. The experience from high-income countries, especially from the US, draws a number of lessons. IP policy frameworks in national legislations and/or at the institutional level should have a number of reservation rights including: research exemptions[83], a research tools policy to ensure access to inventions which primary function is facilitating discovery in research; and policy safeguards to ensure control and dissemination of technologies with humanitarian and social impact (So *et al.,* 2008). As explained by Boettiger and Bennet (2006) and Sampat (2009), institutional policies should contain explicit and clear safeguards to protect the public interest. These concerns specific clauses indicating governments' right to use and commercialize inventions such as "march-in" clauses and right to license to third parties,[84], patenting and licensing exemptions (to prevent aggressive patenting and abusive licensing). Furthermore, policy frameworks may explicitly consider mechanisms in IP management that explicitly support humanitarian applications of new technologies and their dissemination in the least developed regions of the world.

The little evidence available on the relationship between publication and patenting from middle- and low-income countries tends to reject the hypothesis of crowding-out effect between patenting and publication. With regard to publication delay, some studies suggest that this risk is not very important when patent policies provide a grace-period (e.g. Chamas, 2002). There are a few recent studies that suggest that

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need to focus on generating world-class research and critical mass in areas of expertise, as well as developing different types of intermediaries.

[82] As explained by Boettiger and Bennett (2006), many of the negative effects of university patenting identified in the context of the Bayh Dole Act can be traced to the institutional policies structured to maximize university benefits and income, rather than to the Act itself.

[83] The TRIPS agreement allows the use of limited exemptions under Article 30, which has a possible application to the research tool issue as well as others.

[84] Preoccupations at this respect have been expressed regarding the South African and Indian Acts by academics and non-governmental organizations (e.g. UAEM -Universities Allied for Essential Medicines; Medicines sans frontiers).

synergies may arise between scientific activity and patenting.. Yet these studies are based on very short samples and results should be read with care (e.g. see Mitondo and Pourisa (2010) on South African scientists and Shovan and Saha (2010) on Indian scientists; mixed evidence is reported by Raffo (2009 for Argentinean scientists).[85] In a study on Chinese scientists in the field of nanotechnology, Wang and Guan (2010) do not find evidence of adverse effects of patenting on publication activity. They do find however a negative impact when patents are co-owned with corporations or by scientists themselves, which suggests that substitution may arise when researchers are strongly involved in commercialization (and so they may be shifting towards more commercial careers). There is no evidence yet regarding anti-commons effects or difficulties on collaboration. Further research is needed.[86]

Research contracting: IP policies work in tandem with research contracting policies. Available evidence suggests that research institutions having clear policies regarding R&D contracting may perform better in the deployment of industry-science linkages (Caldera and Debande, 2010). Contract research and industry funding is a significant source of funding for universities in countries like Malaysia and South Africa (Wolson, 2007b). It is important to safeguard such relationships and make use of IP instruments in a way to expand and solidify industry linkages. In the design of IP ownership rules and policies for technology transfer either nationally or at the institutional level, careful attention should be given not to disrupt existing industry relationships; in particular where industry funding represents the main source of financing for research activities (Wolson, 2007a; Sibanda, 2009).

Academic spinoffs: Academic entrepreneurship through creation of academic startups involving participation of researchers may have a different relevance to countries (and institutions) according to the level of research capabilities and innovation capacity of firms. As explained by Wright *et al* (2007) in their analysis of mid-range universities in Europe, the promotion of firm creation should be taken with care if a critical mass of researchers has not been achieved. If researchers are increasingly absorbed by firm spinoffs, the development of research capabilities at institutions could be undermined. In this sense, surrogate entrepreneurs and the involvement of students in new firms are helpful strategies. This is currently the practice at some Brazilian and Chinese universities.

Importance of career recognition and faculty motivations: In middle- and low-income countries currently promoting university patenting, the information available so far suggests that recognition of technology transfer activities for career advancement is limited. China, Brazil, Mexico and Malaysia have been moving in this direction following national policy mandates. Making technology transfer activities legitimate missions in research organizations and recognized in tenure track and career promotion are necessary to build a culture of technology transfer. Recent evidence for Indian researchers suggests that, like in high-income countries, non pecuniary incentives, such as peer recognition, collaboration, and reputation,, are strong motivations for scientists to engage in patenting. In a study of two Indian universities, Shovon and Saha (2010) find that two major factors explaining patenting by researchers are

[85] Mitondo and Pourisa (2010) analyzed 70 patents from different offices for inventions by scientists employed by South African universities. They found that authors tended to patent and publish simultaneously, so the same intellectual work informed both products. In contrast, Shovon and Saha (2010) report a non-significant association between publication activity and patenting for researchers at two Indian universities. These studies are however based on very small samples and so further research is needed with larger samples to better understand faculty behavior and patenting.

[86] To prevent the lack of incentives for fundamental research, some countries have created separate funds for research. South Africa for instance, has two funds for research: one focuses on applied research (in which firms and public research institutions can apply) and another fund is dedicated to fundamental research (for public research institutions). In contrast, the Indian Act ignores provisions for the identification and segregation of basic research inventions from applied research and does not include either any special clause that will ensure access to such inventions (Stephen, 2010).

the size of the team and research supervision, particularly faculty attitude towards research supervision.[87] These aspects emphasize the importance of collaborative practices and university management of research activities; that is, the policy importance given to research by faculty authorities. Other interesting elements in academic patenting in India are industry experience by researchers and having faculty trained, with doctoral degree, abroad. Wong and Sing (2010) also report evidence of the importance of industry evidence in explaining patenting at the university level for a group of countries.

5.5 Infrastructure

The role of TTO: The evidence for high-income countries discussed earlier consistently confirms the importance of boundary-spanning institutions such as technology transfer offices (TTOs) and infrastructure (incubators and industrial parks) to technology commercialization. For middle- and low-income countries, TTOs can play a major role at universities and PROs having strong research capabilities. In spite of the important evolution of policy frameworks (Section III) in middle- and low-income countries, there is a tangible need for technology management skills and IP expertise. Skills and proper infrastructure are needed at TTOs to better manage new missions and better link with industry.

The institutional mode of TTOs (internal or external to institutions; regional or national) may accommodate to resource constraints and realistically integrate with the potential technology supply offered. In many developing countries, as in the European case, the promotion of TTOs is currently being sponsored and promoted by national authorities. Institutions in middle- and low-income countries, in addition to the important financial constraints, they face the problems of limited infrastructure and skills for technology transfer. Continual public support is needed for the deployment and sustainability of TTOs. As evidenced for US and Europe, it takes time to build IP portfolios, establish contacts, and develop skills in technology transfer and generate economic returns from them(Siegel *et al.,* 2007; Nelsen, 2007b).[88] Furthermore, as shown by the international experience, universities and PROs willing or having TTOs should devote great attention to recruitment, training, and development of TTOs with broad based commercial skills. They confront the challenge of retaining personal by providing attractive wages to staff and more generally, making technology and IP management careers attractive enough to qualified candidates. [89] As capabilities of innovation by firms improve, the demand for IP specialists increases, which can make more difficult for TTOs to retain personnel (e.g. Brazil and China).

Having a technology transfer agency at a regional or national level can be helpful. In institutions with weak research activity, technologies may not be substantial enough to justify investments in individual TTOs; instead regional consortiums or national TTOs may be deemed more cost-effective and attractive for developing a learning-process. The creation of regional TTOs can also be attractive for other countries. Tasks can be divided among a regional coordinating organization and individual TTOs at universities and PROs.[90] Several examples from Europe and Japan exist from which developing countries

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[87] Albeit the sample study is rather small (49 researchers at Jawaharlal Nehru University (JNU), New Delhi; and the Indian Institute of Technology, Delhi (IITD)), estimations on the patenting activity at the researcher level suggest that patenting is not significantly associated with researchers' publication record.

[88] It may take eight to ten years before a TTO stops losing money, and it may never make your institution any substantial amount (Nelsen, 2007b).

[89] Yet in some emerging countries, such as Brazil there is already a problem of high turnover at TTOs at the largest universities, where employees (often new graduates) are quickly recruited by industry because of their experience in technology transfer.

[90] A two stage process may be relevant for some countries. The creation of regional or national TTOs can be considered in a first stage, allowing the development of economies of learning and experience as well as the pooling of resources. In a second stage, as research institutions increase their pool of inventions with commercial potential, individual units could be created where expertise and better practices from central organizations can be transferred.

can be explored in accordance with national specificities. Germany, Republic of Korea and the UK have experimented with regional offices and lessons can be derived from such experiences (OECD, 2003).

5.6 Firm innovation and regions

Firm innovation: In fostering better linkages with science, any policy aiming at strengthening technology transfer in middle- and low-income countries should be made in parallel with public policies targeting the strengthening of innovation capabilities of firms. These strategies can take the form of matching grants or tax incentives policies for R&D and other innovation activities, and can specifically target industry-science collaboration projects. As stressed by interviews in Costa Rica and Brazil, universities should not be seen as competitors by firms in accessing public funds but rather as strategic partners to enhance firm innovation. University-firm co-ownership is actually expanding in many countries (e.g. China and Japan) reflecting an evolution toward more intense private-public involvement in national innovation systems.

Regional disparity: A last point for reflection is the potential impact that IP policy approaches may have on small and lagging research universities if patenting activity is taken as indicator of performance in the allocation of public funding. Too much emphasis on patent outcomes may contribute to exacerbating the gap in research capabilities across institutions. There is evidence of such effects contributing to regional disparity in China. According to Hong (2008), the geographic concentration of economic and knowledge flows have become salient in China in recent years due to administrative decentralization and economic reforms. Less favored regions have been left further behind not only due to their shortage of local university resources, but also because of the reduced knowledge support outside the region.

5.7 Conclusions

There is no one-size-fits-all solution to the challenge of increasing the impact of science on innovation and economic development. The international experience however provides examples of best practice and lessons to be considered. For middle- and low-countries, the best technology transfer policies will be those that better fit national technology transfer needs, in accordance with local circumstances, and issued in consultation with relevant stakeholders. The transformation of research systems into more proactive institutions is a long-term process, just as the building of a national innovation capacity.

The promotion of technology transfer through patents opens up a new era of opportunity to accelerate transformation of scientific results into innovations, notably in the fields of biotechnology, nanotechnology and life sciences. Many middle- and low-income countries have recently emphasized patenting as an instrument for technology transfer. Patents, however, may not have the same importance across countries, and the approaches used for their exploitation may differ matching the innovation needs of countries and institutions. The literature discussed here has shown that the use of patents requires careful attention and significant resources for their adequate exploitation and promotion. A minimum of policy safeguards need to be adopted in IP policies to prevent undesired effects on science and ensure dissemination of technologies with high social and humanitarian impact.

For policy makers, the promotion of patenting and licensing at universities and PROs is part of a broader policy program to improve general country conditions for innovation and make research systems more competitive and valuable to society. Sustained financial support is needed for research, technology transfer and firm innovation. It is not an easy task. Technology transfer requires specific conditions; many of them are structural and whose results develop over time. Therefore building a technology transfer system demands a comprehensive long-term public policy agenda. An effective technology transfer system requires research and innovation capabilities, appropriate policy frameworks, communication between science and industry, a culture of innovation, technology intermediaries, as well as finance for new firm and technology development. As exposed throughout this paper, success in technology transfer is the result of sustained efforts to bridge the gap between science and society, and commitment by research institutions to contribute to economic and social development. Many middle- and low-income countries are moving in this direction.

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ANNEX

SURVEY ON INTELLECTUAL PROPERTY AND TECHNOLOGY TRANSFER ACTIVITIES BY UNIVERSITIES IN DEVELOPING COUNTRIES[91]

Name of contact : ____
Job position: ____
E mail : ____________________ Telephone: ______________________________

I. General Information of the University

1.1. Name of the University: ______________________________________
1.2. Classification: Public University☐ Private University ☐
1.3 Number of researchers in university: _________
1.4 Total of research budget (Research and development expenditure) in USD:
In 2009: _______ In 2010:__________

II. National preconditions (please cross (X) the relevant case)

2.1. Is technology transfer part of the national economic strategy in your country?
Yes ☐ No ☐

2.2 Is there an adequate intellectual property (IP) system in your country with updated IP laws and regulations?
Yes ☐ No ☐ In process ☐

2.3 Is there a national IP and innovation strategy governing IP ownership of publicly-funded research results and researcher's rights on inventions developed under public funding in your country?
Yes ☐ No ☐ In process ☐

2.4 Are there sufficient sources of public and private funds that could enable an effective technology transfer system in your country?
Yes ☐ No ☐

2.4 Are there research capabilities in your country strong enough to allow the development of new technological competences?
Yes ☐ No ☐

2.5 Is there adequate university-industry collaboration involving technology transfer activities in your country?
Yes ☐ No ☐

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[91] This survey builds on recent surveys conducted in developing countries and extends such analysis by looking at factors affecting patenting and obstacles to commercialization of patents. We included several questions from the PILA Network survey for Latin American countries (Gestion de la Propiedad Intelectual e Industrial en Instituciones de Educación Superior - Buenas Prácticas en Universidades de Latinoamérica y Europa. Available at: http://www.pila-network.org/publicaciones.html) and the survey study "Intellectual Property, Commercialization and Institutional Arrangements at South African Publicly Financed Research Institutions" published by McLean Sibanda in the publication "The Economics of Intellectual Property in South Africa" (WIPO, 2009).

III. Institutional Framework

3.1 Does the university have a policy/guideline relative to the creation of Intellectual Property (IP) (patents, trademarks, design and industrial models, utility models, etc.)?
Yes ☐ No ☐

3.2 Does the university have a policy/guideline relative to R&D activities?
Yes ☐ No ☐

3.3. Does the university have a policy relative to technology transfer activities (e.g. technology services to industry, licensing of intellectual property, research collaboration with industry)?
Yes ☐ No ☐

3.4 Is there a policy regarding ownership of IP? Yes ☐ No ☐

3.4.1 Who owns the results derived from public funded research? Please indicate the relevant case (with X).

Institution only	
Institution with researchers (creator, faculty)	
Institution with other organizations (firms, public research organizations or funding agencies)	
Researchers/Creator only	
Funding or collaborating firm	

3.5 Is there a policy for distribution of revenue stemming from commercialization of IP (example: 33% researchers, 33% the university / the TTO and 33% Department /Faculty): Yes ☐ No ☐
if yes, please indicate such revenue sharing rule: ____

3.6 Does your institution provide incentives to researchers to promote protection and exploitation of IP? Yes ☐ No ☐

3.6.1 If yes, what are these incentives? Please cross (X) the relevant items.

Award or recognition to inventors	
IP is a criteria recognized in the evaluation of researchers	
Economic incentives for registration of IP	
Equity participation in firm creation	
Allowance of temporary leave for firm creation	
Other. Indicate:____________________________________	

IV. Functions of the Technology transfer Organization (TTO)

4.1. How many persons work at this TTO ? _____________
4.2 How many intellectual property professionals work at this TTO ? _____________
4.3 When was this unit created? _____________________
4.4 What is the budget managed by the TTO in your institution (in US dollars) in the last two years? 2009:___________________ 2010: ______________

4.5What are the sources of financing of this budget? Please indicate the share.

Source of funding	Share in total budget %
Own sources	
Institution (university budget)	
Governmental agencies	
Foundations/international organizations	
Firms	
Others. Please indicate:____________________	

4.6 From the following list of activities please indicate who is working on the following activities? Are these activities being done in-house or outside (outsourced)? Please cross (X) the relevant items. If those activities are not implemented at all (neither in-house nor externally) please indicate so in the last column.

Management of IP (activities)	Please indicate if such activity is conducted in-house or contracted to third parties		Activity not conducted at all (neither in-house nor externally)
	In-house	Contracted	
Identification of inventions			
Reception of communications/disclosures			
Search of the state of the art			
Elaboration of the technical descriptive report			
Patenting and registration of other IP before national agencies			
International applications			
Analysis of technical and market viability			
Promotion of technology transfer services and search of potential partners			
Negotiation of contracts			

4.6.1 What other activities does your technology transfer unit conduct? (e.g. training; incubation...)

____

4.7 What kinds of contracts are used in the exploitation of patents? Please cross (X) the relevant items.

R&D contracts	
Consultancy	
Research collaboration	
Confidential agreement NDA agreement	
Licensing contract	
Material Transfer Agreements	
Technology and engineering services	
Clinical Tests	
Contract for assignment / acquisition of IP rights (selling the patent to third parties)	
Employment contracts (rules for the use of patented technology)	
Others (please specify) ____________________________	

IV. Indicators of IP register and commercialization

4.1 Please indicate the total of outputs generated at your institution (TTO).

	Total 2009	Total 2010	Total historic
Scientific publications (in Web of Science, ISI)			
Number of national patent applications			
Number of national patent grants			
Number of international patent applications (PCT; national phase) and grants.			
Number of patents being licensed (in total patents granted at national office) ?			
Number of start-ups created / spin-outs			
Number of patent licensing contracts			
Number of trademarks (national registers)			
Number of utility models (national registers)			
Number of plant varieties (national registers)			
Number of industrial designs (national registers)			
Number of technology contracts (R&D services, technical assistance, engineering, calibration, etc.) not involving patents			
Patent exploitation rate (share of patents in total patents granted at national office that are currently commercialized; either through licensing or start-up)			

V. Factors affecting Patenting at Institutions.

5.1 Please indicate (with a cross: X) the level of importance in each of the factors below noted.

	High importance	Medium importance	Low importance
Finance available for patenting			
Human resources and infrastructure available to screen invention disclosures (and evaluate patentability)			
Lack of patent information or search skills			
Difficulties to screen invention disclosures and asses technology value of inventions (lack of human resources and infrastructure)			
IP policy at the institution			
IP and IP management skills			
Incentives/institutional rewards for researchers (recognition in careers; economic stimulus)			
Awareness of the benefits of IP			
Linkages with industry (to identify market potential technologies)			
Inventions with good commercial potential			
Others (please specify) ______________________________			

VI. Obstacles to the commercialization of patents

6.1 Please indicate (with a cross: X) obstacles to the commercialization of patents:

	Relevant	Not relevant
Lacking expertise and skills for technology transfer management (negotiating drafts, searching partners; managing IP)		
Weak absorptive capacity of local industries		
Lack of trust between researchers and private firms		
Missing IP policy on commercialization at the institution		
Government (constraining) regulations/legislations		
Institutional constraints for researchers to participate in spin-offs and technology transfer activities (right to equity participation; temporary leave)		
Lack of finance to start new firms		
Need for post licensing support		
Stage of development of technologies covered by patents (too embryonic; too basic research)		
Patents covering inventions targeting Northern markets (lack of relevance for local markets)		
Weak protection of IP rights (weak patent system)		
Lacking linkages with industry		