WIPO Economics & Statistics Series

2011

World Intellectual Property Report

The Changing Face of Innovation

WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

WIPO Economics & Statistics Series

2011

World Intellectual Property Report

The Changing Face of Innovation

WIPO
WORLD
INTELLECTUAL PROPERTY
ORGANIZATION

FOREWORD

Innovation is a central driver of economic growth, development and better jobs. It is the key that enables firms to compete in the global marketplace, and the process by which solutions are found to social and economic challenges.

The face of innovation has evolved significantly over the last decades.

First, firms are investing historically unprecedented amounts in the creation of intangible assets – new ideas, technologies, designs, brands, organizational know-how and business models.

Second, innovation-driven growth is no longer the prerogative of high-income countries alone; the technological gap between richer and poorer countries is narrowing. Incremental and more local forms of innovation contribute to economic and social development, on a par with world-class technological inventions.

Third, the act of inventing new products or processes is increasingly international in nature and seen as more collaborative and open.

Fourth, knowledge markets are central within this more fluid innovation process. Policymakers increasingly seek to ensure that knowledge is transferred from science to firms, thereby reinforcing the impact of public research. Moreover, ideas are being co-developed, exchanged and traded via new platforms and intermediaries.

In this new setting, the role of intellectual property (IP) has fundamentally changed. The increased focus on knowledge, the rise of new innovating countries and the desire to protect inventions abroad have prompted a growing demand for IP protection. IP has moved from being a technical topic within small, specialized communities to playing a central role in firm strategies and innovation policies.

Understanding these innovation trends and the associated role of IP is important in order for public policy to support new growth opportunities. The essential questions to ask are whether the design of the current IP system is fit for this new innovation landscape, and how best to cope with the growing demand to protect and trade ideas. To move beyond polarized debates on IP, more fact-based economic analysis is needed. In addition, it is crucial to translate economic research in the field of IP into accessible policy analysis and messages.

I am pleased therefore that WIPO's first World IP Report explores the changing face of innovation. Through this new series, we aim to explain, clarify and contribute to policy analysis relating to IP, with a view to facilitating evidence-based policymaking.

Clearly, this Report leaves many questions open. Where the available evidence is insufficient for making informed policy choices, the World IP Report formulates suggestions for further research. This first edition does not address all the important IP themes – notably, trademarks and branding, copyright and the cultural and creative industries, or the protection of traditional knowledge. We intend to focus on these and other areas in future editions of this series.

Francis GURRY
Director General

ACKNOWLEDGEMENTS

This Report was developed under the general direction of Francis Gurry (Director General). It was prepared and coordinated by a core team led by Carsten Fink (Chief Economist) and comprising Intan Hamdan-Livramento (Economist) and Sacha Wunsch-Vincent (Senior Economist), all from the Economics and Statistics Division.

Chapter 3 draws heavily on a contribution from Josh Lerner and Eric Lin from Harvard Business School.

The IP Statistics and Data Development Sections supplied many of the data used in this Report and made written contributions to Chapters 1 and 4. Special thanks go to Mosahid Khan and Hao Zhou. Ignat Stepanok and Maria-Pluvia Zuñiga contributed to the development of the data methodology and to several sections of Chapter 4.

Background reports were prepared by Suma Athreye, José Miguel Benavente, Daniel Goya, Ove Granstand, Keun Lee, Sadao Nagaoka, Jerry Thursby, Marie Thursby, Yong Yang, and María Pluvia Zuñiga.

Nuno Pires de Carvalho and Giovanni Napolitano from the Intellectual Property and Competition Policy Division provided helpful input for Chapter 3. Ilaria Cameli, Yumiko Hamano, Ali Jazairy and Olga Spasic from the Innovation and Technology Transfer Section contributed to and offered helpful suggestions on Chapter 4.

The Report team benefitted greatly from comments on draft chapters from Alfonso Gambardella, Richard Gilbert, Christian Helmers, Derek Hill, Martin Schaaper, Mark Schankerman, Pedro Roffe, and Jayashree Watal. In addition, several WIPO colleagues also offered helpful suggestions, namely Philippe Baechthold, Juneho Jang, Ryan Lamb, Bruno Le Feuvre, Tomoko Miyamoto, Julio Raffo, Yoshiyuki Takagi and Takashi Yamashita.

Thanks also go to the Association of University Technology Managers (AUTM), Bronwyn Hall, Derek Hill, the Organisation for Economic Co-operation and Development, Maxim Pinkovskiy, Melissa Schilling, and the UNESCO Institute for Statistics for kindly providing data used in this report.

Samiah Do Carmo Figueiredo provided valuable administrative support.

Finally, gratitude is due to Heidi Hawkings and Stephen Mettler from the Communications Division for editing and designing the Report and the Printing and Publication Production Section for their printing services. All worked hard to meet tight deadlines.

DISCLAIMER

This Report and any opinions reflected therein are the sole responsibility of the WIPO Secretariat. They do not purport to reflect the opinions or views of WIPO Member States. The main authors of this Report also wish to exonerate those who have contributed and commented upon it from responsibility for any outstanding errors or omissions.

Readers are welcome to use the information provided in this report, but are requested to cite WIPO as the source.

TECHNICAL NOTES

COUNTRY INCOME GROUPS

This Report relies on the World Bank income classification based on gross national income per capita to refer to particular country groups. The groups are: low-income (USD 1,005 or less); lower middle-income (USD 1,006 to USD 3,975)-; upper middle-income (USD 3,976 to USD 12,275); and high-income (USD 12,276 or more).

More information on this classification is available at *http://data.worldbank.org/about/country-classifications*.

IP DATA

The majority of the IP data published in this Report are taken from the WIPO Statistics Database, which is primarily based on WIPO's annual IP statistics survey and data compiled by WIPO in processing international applications/registrations filed through the Patent Cooperation Treaty (PCT), the Madrid System and the Hague System.

Data are available for download from WIPO's webpage: *www.wipo.int/ipstats/en*. WIPO's annual World Intellectual Property Indicators, freely available on the same webpage, provides additional information on the WIPO Statistics Database.

The patent family and technology data presented in this Report come from the WIPO Statistics Database, the most recent Worldwide Patent Statistical Database (PATSTAT) of the EPO, and from selected national data sources, as indicated in the Report.

Every effort has been made to compile IP statistics based on the same definitions and to ensure international comparability. The data are collected from IP offices using WIPO's harmonized annual IP statistics questionnaires. However, it must be kept in mind that national laws and regulations for filing IP applications or for issuing IP rights, as well as statistical reporting practices, differ across jurisdictions.

Please note that, due to the continual updating of missing data and the revision of historical statistics, data provided in this Report may differ from previously published figures and the data available on WIPO's webpage.

EXECUTIVE SUMMARY

Throughout human history, innovation has been a powerful force for transformation. This arguably holds true now more than ever. However, the face of innovation – the "who", the "how", and the "what for" – has continuously changed.

Understanding these changes is important. In modern market economies, innovation is a key ingredient of sustained economic growth. In high-income countries, studies have estimated that innovation accounts for as much as 80 percent of economy-wide growth in productivity. Research at the firm level has shown that firms that innovate outperform their non-innovating peers. Less is known about innovation and its economic impact in low- and middle-income economies. However, the available evidence similarly suggests that innovating firms in those economies are more productive – especially if applying a broad view of innovation that includes incremental product and process improvements. Indeed, the experience of several East Asian economies has demonstrated how innovation can spur economic catch-up – even if innovation may be only part of the success story of those economies.

For policymakers in particular, it is important to monitor and assess how innovation changes. Governments are key stakeholders in national innovation systems. They directly fund research and provide incentives for firms to invest in innovation – including through the protection of intellectual property (IP). As innovation practices shift, governments need to assess the effectiveness of existing policies and, where necessary, adapt them.

This Report seeks to make an analytical contribution in this respect. It does so in two ways. First, it sheds light on global innovation trends – especially those concerning IP – and assesses the ways in which innovation has really changed. Second, it reviews the available evidence on how IP protection affects innovative behavior and what this evidence implies for the design of IP and innovation policies.

How is the face of innovation changing?

Claims about new innovation models and practices abound. Assessing the significance of those claims requires a dispassionate look at the available data – a task performed in Chapter 1.

The geography of innovation has shifted, although high-income countries still dominate global R&D spending

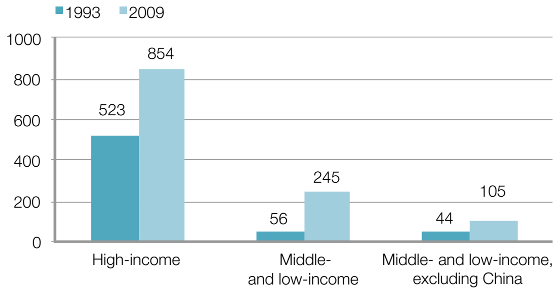
A natural first step is to look at trends in research and development (R&D). Global R&D expenditure almost doubled in real terms from 1993 to 2009. Since this period also saw marked growth of the global economy, the share of global gross domestic product (GDP) devoted to R&D increased at a more modest rate – from 1.7 percent in 1993 to 1.9 percent in 2009. Two other important insights emerge from the available R&D data (see Figure 1):

- Most R&D spending still takes place in high-income countries – around 70 percent of the world total. They spend around 2.5 percent of their GDP on R&D – more than double the rate of middle-income economies.

- Low- and middle-income economies increased their share of global R&D expenditure by 13 percent between 1993 and 2009. China accounts for most of this increase – more than 10 percentage points – propelling China to the world's second largest R&D spender in 2009.

Figure 1: R&D expenditure still comes mainly from high-income countries

Worldwide R&D expenditure, by income group, in 2005 PPP Dollars, 1993 and 2009



See Figure 1.5.

R&D statistics paint only a partial picture of innovation landscapes. The innovation performance of economies depends on broader investment in knowledge beyond formal R&D spending. This includes, above all, investment in education. The introduction of new machinery and equipment is another important component of innovation expenditure, especially in low- and middle-income countries.

Studies have also pointed to the importance of non-technological innovation – including organizational, marketing, design and logistical innovation – as an important driver of firm and economy-wide productivity enhancements. Indeed, data show that firms' investment in all types of intangible assets has grown more rapidly than their investment in tangible assets; in selected countries, firms even invest more in intangible than in tangible assets. However, few hard data exist to rigorously assess whether non-technological innovation has risen in relative importance – not least because such innovation often complements technological breakthroughs.

The innovation process is increasingly international in nature

Clear evidence exists that innovation is increasingly international in nature. Greater mobility of students, highly-skilled workers and scientists has spurred the international exchange of knowledge. There also has been a sharp increase in the share of peer-reviewed science and engineering articles with international co-authorship, and a rising share of patents that list inventors from more than one country. More and more, multinational firms are locating their R&D facilities in a variety of countries – with certain middle-income economies seeing particularly fast growth. The rising share of middle-income countries in the global economy is, in turn, reorienting innovation towards the demands of those countries.

Innovation is seen to have become more collaborative and open... but is this perception correct?

One much-discussed element of the new innovation paradigm is the increasingly collaborative nature of the innovation process. Indeed, the available data confirm that there is greater collaboration in some respects. The above-mentioned trend of more frequent international co-patenting points to greater collaboration at the international level. In addition, the available data on R&D alliances have shown upward trends in some sectors, although not necessarily in recent years, and the reliability of those data is weak.

Heightening perceptions of greater collaboration, scholars and business strategists have emphasized that innovation is becoming increasingly "open". In particular, firms practicing open innovation strategically manage inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external uses of their intangible assets. "Horizontal" collaboration with similar firms is one important element of open innovation, but it also includes "vertical" cooperation with customers, suppliers, universities, research institutes and others.

Assessing the true scale and importance of open innovation is challenging. For one, it is difficult to draw a clear distinction between open innovation strategies and long-standing collaborative practices, such as joint R&D, joint marketing or strategic partnerships. In addition, certain elements of open innovation strategies – such as new policies internal to firms or informal knowledge exchanges – cannot easily be traced. Anecdotally, examples of truly new approaches abound – notably, so-called crowd-sourcing initiatives, prizes and competitions, and Internet platforms on which firms can post challenges. Modern information and communications technologies (ICTs) have facilitated many of these approaches.

IP ownership has become more central to business strategies

Turning to the IP system, there is every indication that IP ownership has become more central to the strategies of innovating firms. IP policy has, therefore, moved to the forefront of innovation policy.

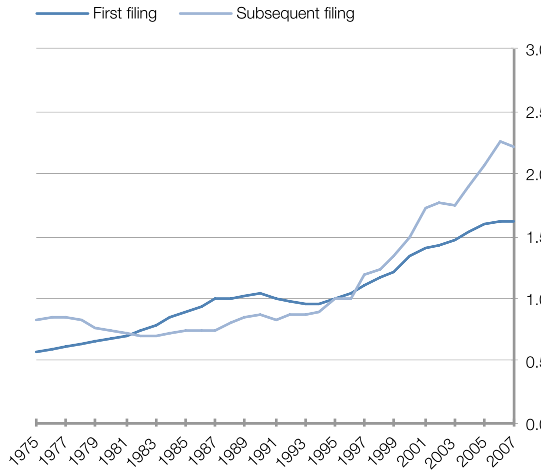
Demand for patents has risen from 800,000 applications worldwide in the early 1980s to 1.8 million in 2009. This increase has occurred in different waves, with Japan driving filing growth in the 1980s, joined by the United States (US), Europe and the Republic of Korea in the 1990s and, more recently, by China.

There are many causes of this rapid increase in patenting, including some which are specific to countries and industries. However, two key forces stand out:

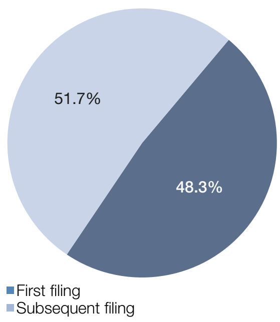
- Dividing the growth in patenting worldwide into so-called first filings – approximating new inventions – and subsequent filings – primarily filings of the same invention in additional countries – shows that the latter explains slightly more than one-half of that growth over the last 15 years (see Figure 2). Patent applicants increasingly seek to protect their patents abroad and, indeed, in a larger number of countries, reflecting greater economic integration.
- Comparing growth in the number of first filings to growth in real R&D expenditure shows that, for the world as a whole, the latter has grown somewhat faster than the former. This suggests that growth in patenting is rooted in underlying knowledge investment. As discussed further below, however, patenting and R&D trends vary markedly across countries and industries, with important implications for how firms innovate.

Figure 2: Patenting abroad is the main driver of worldwide patenting growth

Patent applications by type of application, indexed 1995=1



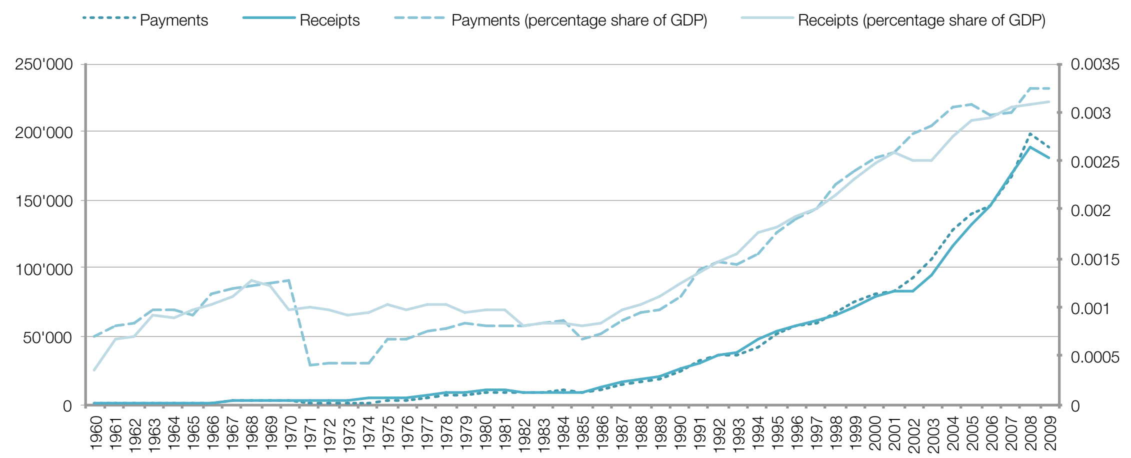
Contribution of first and subsequent applications to total growth, in percent, 1995-2007



See Figure 1.20.

Figure 3: International royalty and licensing payments and receipts are growing

RLF payments and receipts, in USD millions (left) and as a percentage share of GDP (right), 1960-2009



See Figure 1.26.

Demand for other IP rights – which firms often use as a complement to patents – has also seen marked growth. Trademark applications worldwide increased from 1 million per year in the mid-1980s to 3.3 million in 2009. Similarly, industrial design applications worldwide more than doubled from about 290,000 in 2000 to 640,000 in 2009. Greater internationalization is also an important factor behind the rising demand for protection of these forms of IP. However, little is known about what precisely has driven their filing growth and to what extent their role in business strategies has shifted.

Knowledge markets based on IP rights are on the rise, though still nascent

A final important trend concerns the rise of IP-based knowledge markets. Evidence suggests that the tradability of IP has increased over the last few decades. This is reflected in more frequent licensing of IP rights and the emergence of new technology market intermediaries.

Figure 3 depicts the growth of cross-border licensing trade in the world economy, showing an acceleration of such trade since the 1990s. In nominal terms, international royalty and licensing fee (RLF) receipts increased from USD 2.8 billion in 1970 to USD 27 billion in 1990, and to approximately USD 180 billion in 2009 – outpacing growth in global GDP. There are far fewer data on domestic IP transactions, but selected company information confirms this trend.

Technology market intermediaries have existed for a long time. However, new "market makers" have emerged, such as IP clearinghouses, exchanges, auctions and brokerages. Many of them use modern ICTs for valuing IP rights and matching buyers and sellers. As further discussed below, another rapidly growing form of intermediation over the last decades has been the establishment of technology transfer offices (TTOs) at universities and public research organizations (PROs).

While only limited analysis is available on the size and scope of actual IP transactions, the available evidence on patent licensing, auctions and other IP-based transactions suggests that trading activity remains at incipient levels. For example, firms typically license less than 10 percent of their patents. Certainly, technology markets are still small relative to the revenue of firms' or the overall output of economies. However, they increasingly shape how innovation takes place and therefore deserve careful attention.

Many of the above-outlined changes in the innovation landscape are challenging long-standing business practices. Firms need to adapt in order to remain competitive. But do these changes also require a rethinking of the policy framework for innovation? This question is at the heart of the remainder of the Report. The Report first offers a general introduction to the economic literature on how IP protection affects innovation; it asks, in particular, how the views of economists have changed in the last few decades (Chapter 2). It then returns to the theme of collaboration, first looking at collaborative practices between firms (Chapter 3) and then at collaboration between public research institutions and firms (Chapter 4).

How have economists' views on IP protection evolved?

Understanding how IP protection affects innovative behavior has long been a fertile field in economic research. Important insights from the past still shape how economists view the IP system today. Above all, compared to other innovation policies, IP protection stands out in that it mobilizes decentralized market forces to guide R&D investment. This works especially well where private motivation to innovate aligns with society's technological needs, where solutions to technological problems are within sight, and where firms can finance upfront R&D investment. In addition, the effectiveness of different IP instruments depends on the absorptive and innovative capacity of firms, which varies considerably across countries at different levels of economic development.

Difficult trade-offs exist in designing IP rights, not least because IP protection has multifaceted effects on innovative behavior and market competition. As technologies advance and business models shift, optimally balancing these trade-offs represents a continuing high-stakes challenge.

In more recent history, economists have refined their view of the IP system – partly as a result of new research and partly due to real world developments. The patent system has received particular attention.

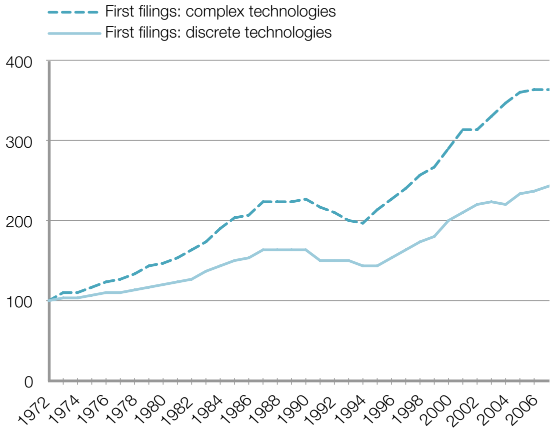
Patent portfolio races complicate cumulative innovation processes

Economists have long recognized that innovation seldom happens in isolation; one firm's solution to a problem typically relies on insights gained from previous innovation. Similarly, in competitive markets, firms innovate simultaneously and develop technologies that may complement each other. The rapid increase in the number of patent filings has, in turn, raised concerns about patents hindering cumulative innovation. Indeed, patenting activity has grown especially fast for so-called complex technologies. Economists define complex technologies as those that consist of numerous separately patentable inventions with possibly widespread patent ownership; discrete technologies, by contrast, describe products or processes made up of only a few patentable inventions. Figure 4 shows that complex technologies have seen faster growth in patent applications worldwide.

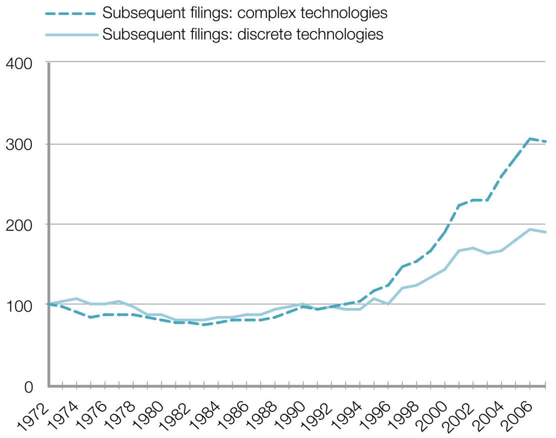
Figure 4: Complex technologies see faster patenting growth

Patent filings for complex versus discrete technologies, 1972=100, 1972-2007

First filings



Subsequent filings



See Figure 2.1.

What accounts for the difference in growth rates? It partly reflects the nature of technological change. For example, complex technologies include most ICTs which have experienced rapid advances over the last three decades. However, economic research suggests that faster growth in complex technologies is also due to a shift in patenting strategies.

Research which originally focused on the semiconductor industry has shown that firms proactively build up large patent portfolios. One motivation for such portfolios is to ensure a firm's freedom to operate in its innovation space and to preempt litigation. A second motivation for firms to create these portfolios is to strengthen their bargaining position vis-à-vis competitors. In particular, firms owning many patents in a crowded technology space can preempt litigation by credibly threatening to countersue competitors. In addition, they are in a better position to negotiate favorable cross-licensing arrangements which are often needed to commercialize new technologies.

In addition to semiconductors, patent portfolio races have been documented for other complex technologies – ICTs in general and, in particular, telecommunications, software, audiovisual technology, optics and, more recently, smartphones and tablet computers. Even though these portfolio races often take place in industries making fast technological progress, there is concern that they may slow or even forestall cumulative innovation processes. In particular, entrepreneurs facing dense webs of overlapping patent rights – or patent thickets – may forgo research activity or shelve plans for commercializing promising technologies.

Patents facilitate specialization and learning

A second area of refined thinking concerns the role of patents in modern technology markets. Research has shown that patents enable firms to specialize, allowing them to be more innovative and efficient at the same time. In addition, they allow firms to flexibly control which knowledge to guard and which to share so as to maximize learning – a key element of open innovation strategies.

Such learning can also take place when patents are disclosed to the public. Little evidence is available on the value of patent disclosure, although some surveys have revealed that published patents are indeed an important knowledge source for firms conducting R&D – more so in Japan than in the US and Europe. Yet, the patent literature represents a valuable source of knowledge for creative minds anywhere in the world. In addition, the easy availability of millions of patent documents to anyone connected to the Internet has arguably created new catch-up opportunities for technologically less developed economies.

Well-functioning patent institutions are crucial

Finally, economic research has come to recognize the crucial role played by patent institutions in shaping innovation incentives. Patent institutions perform the essential tasks of ensuring the quality of patents granted and providing balanced dispute resolution.

Unprecedented levels of patenting have put these institutions under considerable pressure. Many patent offices have seen growing backlogs of pending applications. In 2010, the number of unprocessed applications worldwide stood at 5.17 million. In absolute terms, the patent offices of Japan and the US as well as the European Patent Office account for the largest office backlogs. However, relative to annual application flows, several offices in middle-income countries face the most substantial backlogs. The increasing size and complexity of patent applications have added to the "examination burden" of offices.

The choices patent offices face can have far-reaching consequences on incentives to innovate. These include the amount of fees to charge, how to involve third parties in the patenting process, how best to make use of ICTs and the level and type of international cooperation to pursue. In making these choices, a key challenge is to reconcile incentives for efficient office operations with a patenting process that promotes society's best interest.

Do markets forces optimally balance collaboration and competition?

Firms increasingly look beyond their own boundaries to maximize their investment in innovation. They collaborate with other firms – either in the production of IP or on the basis of IP ownership in commercializing innovation.

Collaboration can benefit firms and society

Joint IP production occurs through R&D alliances, in particular contractual partnerships and equity-based joint ventures. Data on such alliances are limited and sometimes difficult to interpret, but they suggest that firms in the ICT, biotechnology and chemical industries most frequently enter into such alliances.

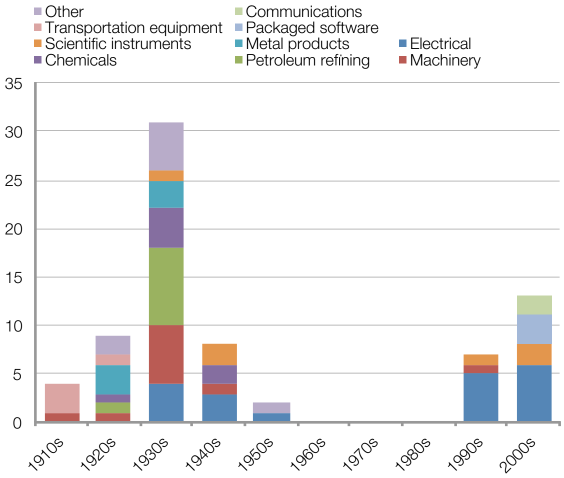
Joining forces with competitors offers several benefits. A firm can learn from the experience of others, reduce costs by dividing efforts, share risk and coordinate with producers of complementary goods. Society usually benefits from such collaboration as it enhances the efficiency and effectiveness of the innovation process.

Collaboration between firms extends beyond the joint production of IP. In many cases, firms only join forces when, or even after, they commercialize their technologies. As explained above, the fast growth of patenting in complex technologies has given rise to patent thickets, whereby patent rights are distributed over a fragmented base of patent holders. Those seeking to introduce products that use such technologies face the high cost of negotiating with multiple parties. If each technology is essential, a negotiation failure with any of the patent holders amounts to a failure with all.

One solution is for firms to pool their patents, sharing them with other patent holders and sometimes licensing them to third parties as a package. Patent pools are not a new collaborative practice; they have existed for more than a century. The available data point to their widespread use in the first half of the 20th century (see Figure 5). In the period after the Second World War, the more skeptical attitudes of competition authorities drastically reduced the formation of new pools. However, this has again changed in the last two decades, with a new wave of pools emerging, especially in the ICT industry where patent thickets have proliferated.

Figure 5: The ICT industry dominates the recent wave of patent pools

Number of patent pools by industry



See Figure 3.4.

As in the case of R&D alliances, there is a compelling case that patent pools are not only beneficial to participating patent holders, but also to society. They enable the introduction of new technologies and promote the interoperability of different technologies. The latter aspect is especially important where technology adoption requires standard setting. Indeed, patent pools are often formed as a result of standard-setting efforts.

Notwithstanding their benefits, leaving the formation of collaborative ventures to private market forces may not always lead to socially optimal outcomes; firms may either collaborate below desirable levels or they may do so in an anticompetitive manner.

Market forces may not always lead to desirable levels of collaboration...

Insufficient levels of collaboration – whether in the production or commercialization of IP – may arise from conflicts of interest between potential collaborators. Fears of free riding, risk shifting and other forms of opportunistic behavior may lead firms to forgo mutually beneficial cooperation. Differences in business strategies between specialized R&D firms and "vertically" integrated R&D and production firms can add to negotiation gridlock.

In principle, the failure of private markets to attract optimal levels of collaboration provides a rationale for government intervention. Unfortunately, the available evidence offers little guidance to policymakers on how such market failures are best resolved. This is partly because the benefits of and incentives for collaboration are highly specific to particular technologies and business models, and also because it is difficult to evaluate how often potentially fruitful collaboration opportunities go unexplored in different industries.

Some governments promote collaboration among firms through fiscal incentives and related innovation policy instruments. In addition, there are incentive mechanisms for sharing patent rights – for example, discounts on renewal fees if patent holders make available their patents for licensing. However, as greater technological complexity and more fragmented patent landscapes have increased the need for collaboration, there arguably is scope for creative policy thinking on how best to incentivize the licensing or sharing of patent rights.

... and they may sometimes result in anticompetitive practices

The problem of anticompetitive collaborative practices seems to be easier to address from a policymaker's viewpoint. Such practices are generally more observable, and authorities can assess the competitive effects of collaborative agreements on a case-by-case basis. In addition, some consensus exists about the type of collaborative practices that should not be allowed or that, at the least, trigger warning signs. Nonetheless, evaluating the competitive effects of specific collaborative agreements remains challenging. Technologies move fast, and their market impact is uncertain. In addition, many low- and middle-income countries have less developed institutional frameworks for enforcing competition law in this area – although they are likely to benefit from the enforcement actions of high-income countries, where most collaborative agreements with global reach are concluded.

How to harness public research for innovation

Universities and PROs play a key role in national innovation systems. Beyond their mission to educate, they account for substantial shares of total R&D spending. They also perform most of the basic research carried out in their countries. This is especially so in middle-income countries; for example, the share of universities and PROs in total basic research is close to 100 percent for China, 90 percent for Mexico and 80 percent for the Russian Federation.

Close interaction with public research helps firms to monitor scientific advances that are likely to transform technologies. It also facilitates joint problem solving and opens up new avenues for research.

Public-private knowledge exchanges occur through a number of channels. One is the creation of IP in the public sector that is licensed to firms for commercial development.

Public policies have encouraged the commercialization of scientific knowledge...

The last three decades have seen the emergence of targeted policy initiatives to incentivize university and PRO patenting, and subsequent commercial development. Almost all high-income countries now have institutional frameworks to this effect. One general trend has been for universities and PROs to take institutional ownership of the inventions researchers generate, and to pursue their commercialization through TTOs. More recently, a number of middle- and low-income countries have also explored how technology transfer and the development of industry-university collaboration are best promoted.

... leading to rapid growth in patenting by universities and PROs

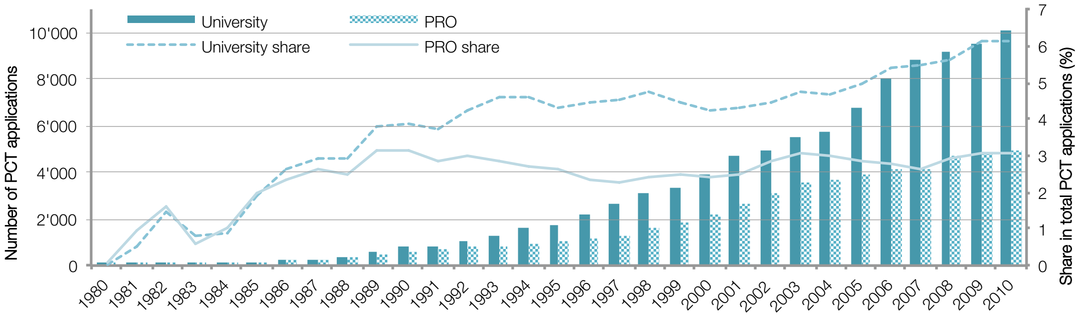
Accordingly, there has been a marked increase in patent applications by universities and PROs – both in absolute terms and as a share of total patents filed. Figure 6 depicts this trend for international patent filings under the Patent Cooperation Treaty (PCT) system.

High-income countries have been responsible for most of the university and PRO filings under the PCT. However, such filings have also grown rapidly in certain middle-income countries. Among them, China leads in terms of university applications, followed by Brazil, India and South Africa. Compared to university patenting, the distribution of middle-income country PRO filings is more concentrated. Chinese and Indian PROs alone account for 78 percent of the total. They are followed by PROs from Malaysia, South Africa and Brazil.

National patent statistics confirm the prominence of university patenting in China; they also reveal a high share of PRO patenting for India (see Figure 7).

Figure 6: University and PRO patenting is on the rise

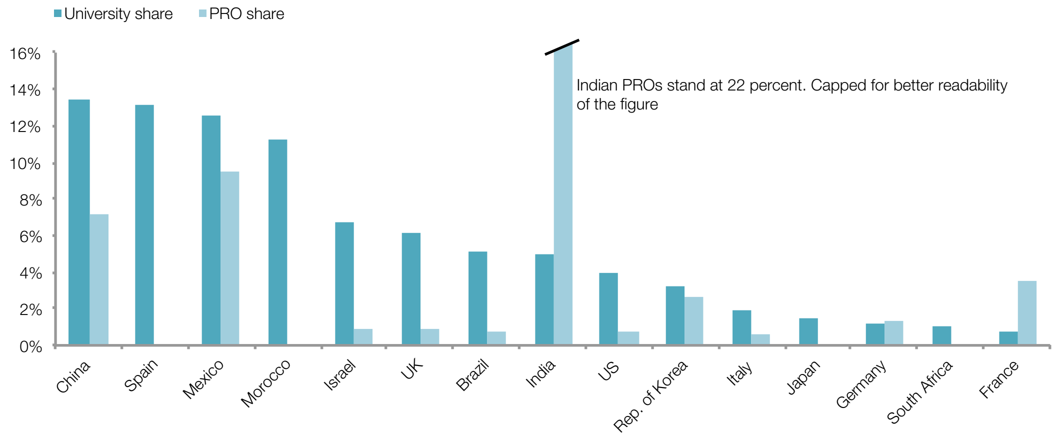
World PRO and university PCT applications, absolute numbers (left) and as a percentage of total PCT applications (right), 1980-2010



See Figure 4.3

Figure 7: University and PRO patenting is prominent in China and India

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



See Figure 4.10

Universities and PROs have also experienced growth in licensing revenue. This growth has occurred from low initial levels and is still fairly concentrated; only selected institutions, few scientific fields and a small number of patents account for the bulk of licensing revenue. Compared to overall public research budgets, licensing income remains small. In low- and middle-income countries, university and PRO patents are used even less for technology transfer. However, recent trends suggest that revenue flows are diversifying, in terms of both the number of beneficiary institutions and the number of countries.

Policy reforms have multifaceted effects on research institutions, firms, the science system and the economy – yet important lessons are emerging

Reforms aimed at incentivizing university and PRO patenting and licensing have multifaceted effects on research institutions and firms but also, more broadly, on the science system and on economic growth. The evidence – mostly focusing on high-income countries – yields the following broad conclusions:

- Patenting can make an important difference in widening opportunities for commercializing university inventions. Turning academic ideas into innovation often requires substantial private investment in development.

- There are important synergies between scientists' academic activity and their interactions with private firms. Such interactions not only take place through the licensing of patents, but also through R&D collaboration, conference participation and scientific publishing. Indeed, the evidence suggests that the various channels of technology transfer complement each other. For example, researchers may find that their patenting activity usefully informs their scientific activity, and vice-versa.

- Studies have pointed to several successful elements of institutional design. Well-defined university regulations on IP ownership and on the participation of researchers in technology transfer matter. Performance incentives for researchers need to appropriately balance entrepreneurial activity and scientific achievement. Finally, TTOs operating at a sufficient scale and helping to standardize relationships with licensees can lower the transaction costs of technology transfer.

- The evidence is more ambiguous as to the best ownership model for public research. While the general trend has been towards institutional ownership, it is not clear whether this model is necessarily superior to others.

- Setting up successful frameworks for technology transfer that deliver tangible benefits takes time and resources. In particular, it not only requires legal reforms, but also cultural change and the creation of new institutions.

Legitimate concerns exist about the potentially negative effects that patenting and other entrepreneurial activity by researchers may have on scientific performance.

- Reduced knowledge sharing among scientists and crowding-out of scientific research are often-cited downsides. The evidence on these effects is ambiguous, although it does not suggest radically negative effects. Much depends on researchers' performance incentives. Moreover, interactions with the private sector can lead to improved scientific performance.

- Another source of concern is that university and PRO patenting may reduce the diversity of follow-on research and access to essential research tools. A few studies confirm this concern. However, most of the evidence to this effect is case-specific and limited to the life sciences.

Many of these conclusions are likely to apply to low- and middle-income economies as they do to high-income economies. However, the different environment in which innovation takes place in these economies raises additional questions.

One is the extent to which greater university and PRO patenting in richer countries may reduce poorer countries' access to key technologies and international scientific cooperation. Another is whether the weaker absorptive capacity of firms and more limited science-industry linkages would favor channels of technology transfer other than IP-based licensing. Different stages of development and different innovation systems require tailor-made approaches to IP-based incentives for commercializing public research.

Only limited guidance is available to policymakers on these questions. At the same time, high-income countries still struggle with many of the same challenges. There is no perfect blueprint that lends itself to universal adoption. This caveat also extends to the development of safeguards against the potentially negative consequences of university and PRO patenting. Selected institutions have pioneered such safeguards; however, it is too early to fully assess their effectiveness.

Conclusion

The evidence presented in this Report is intended to inform policymakers. While some innovation trends are well understood, others are not. The Report points to a number of areas where more statistical data and new investigations could offer fresh insights relevant to policymaking.

Surely, the face of innovation will further evolve in the coming years and decades. Some trends are bound to continue – above all the shifting geography of innovation. Others will come as a surprise. An unvarnished look at today's evidence and policy challenges – as attempted in this Report – will hopefully stimulate thought on how best to manage the future.

TABLE OF CONTENTS

CHAPTER 1
The changing nature of innovation and intellectual property

CHAPTER 2
The economics of intellectual property – old insights and new evidence

CHAPTER 3
Balancing collaboration and competition

CHAPTER 4
Harnessing public research for innovation – the role of intellectual property

CHAPTER 1 THE CHANGING FACE OF INNOVATION AND INTELLECTUAL PROPERTY

Innovation is a central driver of economic growth and development. Firms rely on innovation and related investments to improve their competitive edge in a globalizing world with shorter product life cycles. Innovation also has the potential to mitigate some of the emerging problems related to health, energy and the environment faced by both richer and poorer countries. Overcoming barriers to innovation is hence a recurring and increasingly prominent business and policy challenge.

At the same time, our understanding of innovative activity, the process of innovation itself and the role of IP within that process are in flux. Among the factors that have influenced innovation over the last two decades are structural shifts in the world economy, the steady globalization of innovative activity, the rise in new innovation actors and new ways of innovating.

This chapter assesses the changing face of innovation and the corresponding new demands on the intellectual property (IP) system. The first section sets out the central role of innovation, while the second describes what has been labeled a new "innovation paradigm". The third section discusses the implications of this for IP.

1 The Oslo Manual defines four types of innovation: product innovation (new goods or services or significant improvements to existing ones), process innovation (changes in production or delivery methods), organizational innovation (changes in business practices, workplace organization or in a firm's external relations) and marketing innovation (changes in product design, packaging, placement, promotion or pricing) (OECD & Eurostat, 2005).

2 For some examples of the classic literature in this field, see Edquist (1997); Freeman (1987); Lundvall (1992); and Fagerberg *et al*. (2006).

1.1

Innovation as the driving force behind economic growth and development

Although there is not one uniquely accepted definition, innovation is often defined as the conversion of knowledge into new commercialized technologies, products and processes, and how these are brought to market.[1] Innovation often makes existing products and processes obsolete, leading to firms' entry, exit and associated entrepreneurship.

In recent decades, economists and policymakers have increasingly focused on innovation and its diffusion as critical contributors to economic growth and development.[2] Investments meant to foster innovation, such as spending on research and development (R&D), are found to generate positive local and cross-border impacts, which play an important role in the accumulation of knowledge. In other words, thanks to these so-called "spillovers" the benefits of innovative activity are not only restricted to firms or countries that invest in innovation.

While the importance of "creative destruction" was highlighted in the early 20th century, more recent economic work stresses the role that various factors play in driving long-run growth and productivity.[3] These include not only formal investment in innovation such as R&D, but also learning-by-doing, human capital and institutions.

3 See Schumpeter (1943). The endogenous growth models and quality ladder models theorize that innovation drives long-run aggregate productivity and economic growth. See Grossman and Helpman (1994); Romer (1986); Romer (2010); Grossman and Helpman (1991); and Aghion and Howitt (1992).

A voluminous empirical literature has examined the relationship between innovative activity and productivity growth at the firm-, industry- and country-level. However, due to data limitations, earlier empirical work in this area mostly relied on two imperfect measures of innovation, namely R&D spending and patent counts. In recent years, innovation surveys and accounting exercises relating to the measurement of intangible assets have emerged as new sources of data (see Boxes 1.1 and 1.2).

Most empirical studies on the relationship between innovation and productivity have focused solely on high-income economies and the manufacturing sector. As early as the mid-1990s, the economic literature suggested that innovation accounted for 80 percent of productivity growth in high-income economies; whereas productivity growth, in turn, accounted for some 80 percent of gross domestic product (GDP) growth.[4] More recent studies at the country-level demonstrate that innovation – as measured by an increase in R&D expenditure – has a significant positive effect on output and productivity.[5]

At the firm-level, there is emerging but increasingly solid evidence that demonstrates the positive links between R&D, innovation and productivity in high-income countries.[6] Specifically, these studies imply a positive relationship between innovative activity by firms and their sales, employment and productivity.[7] Innovative firms are able to increase efficiency and overtake less efficient firms. Firms that invest in knowledge are also more likely to introduce new technological advances or processes, yielding increased labor productivity. In addition, a new stream of research stresses the role of investing in intangible assets for increased output and multifactor productivity growth (see Box 1.1).[8] While it is assumed that process innovation has a direct effect on a firm's labor productivity, this is harder to measure.[9]

Clearly, the causal factors determining the success and impact of innovation at the firm-level are still under investigation. An increase in a firm's R&D expenditure or the introduction of process innovation alone will not automatically generate greater productivity or sales. Many often connected factors inherent in the firm or its environment contribute to and interact in improving a firm's performance.

4 See Freeman (1994).
5 For an overview, see Khan and Luintel (2006) and newer studies at the firm level, such as Criscuolo *et al.* (2010).
6 See, for instance, Crepon *et al.* (1998); Griffith *et al.* (2006); Mairesse and Mohnen (2010); and OECD (2010a).
7 See Evangelista (2010); OECD (2010a); OECD (2009c); Guellec and van Pottelsberghe de la Potterie (2007); and Benavente and Lauterbach (2008).
8 See OECD (2010b).
9 See Hall (2011).

Box 1.1: Intangible assets play an important role in firm performance

Firms spend considerable amounts on intangible assets other than R&D, such as corporate reputation and advertising, organizational competence, training and know-how, new business models, software and IP (copyright, patents, trademarks and other IP forms).

Business investment in intangible assets is growing in most high-income economies and, in a number of countries, it matches or exceeds investment in tangible assets such as buildings, equipment and machinery.[10] As a result, intangible assets now account for a significant fraction of labor productivity growth in countries such as Austria, Finland, Sweden, the United Kingdom (UK) and the United States of America (US). Data for Europe show that investment in intangibles ranges from 9.1 percent of GDP in Sweden and the UK, to around 2 percent of GDP in Greece.[11] This is considerably higher than the scientific R&D investment which, for example, stands at 2.5 percent of GDP in Sweden and 0.1 percent of GDP in Greece. For the US, Corrado, Hulten & Sichel (2007) estimate investment in intangible assets at United States Dollars (USD) 1.2 trillion per year for the period 2000-2003. This represents a level of investment roughly equal to gross investment in corporate tangible assets. Depending on the depreciation rate, the stock of intangible assets may be five to ten times this level of investment. In comparison, scientific R&D makes up for only USD 230 billion.

Finally, complementary research based on market valuations of firms in Standard & Poor's 500 Index indicates that intangible assets account for about 80 percent of the average firm's value.[12] The physical and financial accountable assets reflected in a company's balance sheet account, in turn, for less than 20 percent.

Furthermore, innovation-driven growth is no longer the prerogative of high-income countries.[13] The technology gap between middle-income and high-income countries has narrowed (see Section 1.2).[14] In recent years, it has been shown that catch-up growth – and more generally the spread of technology across countries – can now happen faster than ever before. This has been exemplified by countries such as the Republic of Korea and later China.[15]

Differences in innovative activity and related technological gaps between countries are a significant factor in explaining cross-country variation in income and productivity levels.[16] According to several studies, roughly half of cross-country differences in per capita income and growth can be explained by differences in total factor productivity, a measure of an economy's long-term technological change or dynamism.[17] In addition, the variation in the growth rate of GDP per capita is shown to increase with the distance from the technology frontier. Countries with fewer technological and inventive capabilities generally see lower and more diverse economic growth than do richer countries.

As a result, reducing income gaps between economies is directly linked to improved innovation performance,[18] which is in part driven by spillovers from high-income to other economies. In other words, total factor productivity depends to a large degree on the ability of countries, industries or firms to adopt technologies and production techniques of countries and firms with higher levels of technological development.

10 See Gil and Haskell (2008); OECD (2010d); and van Ark and Hulten (2007).
11 See European Commission (2011).
12 See Ocean Tomo (2010). The S&P 500 is a free-floating, capitalization-weighted index, published since 1957, of the prices of 500 large-cap common stocks actively traded in the US. The stocks included in the S&P 500 are those of large publicly-held companies that trade on either of the two largest American stock market exchanges: the New York Stock Exchange and the NASDAQ.
13 See Soete and Arundel in UNESCO (2010) and Bogliacino and Perani (2009).
14 See World Bank (2008).
15 See Romer (1986); Long (1988); and Jones and Romer (2010).
16 See Fagerberg (1994); Hall and Jones (1999); Fagerberg *et al.* (2009); Klenow Rodríguez-Clare (1997); Griliches (1998); and Parisi *et al.* (2006).
17 See Jones and Romer (2010); Guinet *et al.* (2009); and Bresnahan and Trajtenberg (1995).
18 See Hulten and Isaksson (2007).

These spillovers are frequently driven by knowledge acquired through channels such as foreign direct investment (FDI), trade, licensing, joint ventures, the presence of multinationals, migration and/or collaboration with firms from higher-income countries.[19] Strategies for acquiring, adapting, imitating and improving technologies and existing techniques in relation to local conditions are key for innovation. Developing innovative capacity requires complementary in-house innovation activity (see Box 2.2).[20] In addition, certain framework conditions, adequate human capital and absorptive capacity are necessary at the country- and firm-level in order to benefit from innovation spillovers. The literature refers to the necessary presence of functioning "national innovation systems" with linkages between innovation actors and a government policy that underpins innovation activity.[21]

On the whole, however, too little is known about how innovation takes place in lesser developed economies, how it diffuses and what its impacts are.

That does not mean that no evidence in this area exists. Surveys confirm that innovation – understood broadly – occurs frequently in low- and middle-income economies.[22] The literature concludes that the impacts of innovation can be proportionately much greater in these economies than in high-income economies. In particular, cumulative innovation – incremental innovation where one builds on existing products, processes and knowledge (see Subsection 2.2.2) – is shown to have a significant social and economic impact.[23]

As firms in less developed economies are, at times, far from the technology frontier, they have dissimilar technological requirements and innovate differently. Process innovation and incremental product innovation play a more important role in firm performance than does product innovation. Improvements in maintenance, engineering or quality control, rather than fresh R&D investment, are often the drivers of innovation. Recent examples in Africa or other low-income economies such as Bangladesh or Rwanda show that local firms or other organizations introduce novel product or process innovation in fields such as finance (e-banking), telecommunications, medical technologies and others. In conclusion, the relationship between innovation and productivity in less developed economies is not clear-cut. Studies do not always find that technological innovation impacts on productivity, in particular where a narrow definition of product-based technological innovation is used.[24] A few studies on China and certain Asian countries conducted at the aggregate country-level even conclude that factor accumulation, rather than productivity increases, explains the majority of the recent growth.[25]

Firm-level studies conducted in lower- and middle-income economies – mainly done for Asia and Latin America – do in turn provide evidence for the strong positive relationship between innovation and productivity, or innovation and exports, as long as innovation is viewed more broadly than technological product innovation. The literature also concludes that firms in less developed economies that invest in knowledge are better able to introduce new technological advances, and that firms which innovate have higher labor productivity than those that do not.

19 In the context of developing countries, particularly for those in the early stages of development, technology transfer from foreign high-income economies and the spillover effects from foreign investment have been considered the most important sources of innovation, since most such countries lack the capital and the skills to conduct state-of-the-art research.

20 See Cohen and Levinthal (1990).

21 See Jones and Romer (2010).

22 For full references and a discussion, see Crespi and Zuñiga (2010).

23 See Fagerberg *et al.* (2010).

24 See the many country-specific studies of Micheline Goedhuys and her co-authors at *http://ideas.repec.org/f/pgo205.html.*

25 See Anton *et al.* (2006); Young (1993); and Young (1995). This might, however, have to do with measurement issues related to embodied technologies.

1.2

The shifting nature of innovation

While there is consensus on the importance of innovation, our understanding of innovative activity and the process of innovation itself continue to change.

First, the way innovation is perceived and understood has evolved over the last two decades. Previously, economists and policymakers focused on R&D-based technological product innovation, largely produced in-house and mostly in manufacturing industries. This type of innovation is performed by a highly educated labor force in R&D-intensive companies with strong ties to leading centers of excellence in the scientific world.[26]

The process leading to such innovation was conceptualized as closed, internal and localized. Technological breakthroughs were necessarily "radical" and took place at the "global knowledge frontier", without allowing for the possibility of local variations or adaptations of existing technologies. This also implied the existence of leading and lagging countries – i.e., the "periphery" versus the "core" – with low- or middle-income economies naturally catching up to more advanced ones. According to this view, firms from poorer countries were passive adopters of foreign technologies.

Today, innovation capability has been seen less in terms of the ability to discover new technological, state-of-the-art inventions. The literature now emphasizes the ability to exploit new technological combinations, the notion of incremental innovation and "innovation without research".[27] Furthermore, non-R&D-innovative expenditure, often part of later phases of development and testing, is an important and necessary component of reaping the rewards of technological innovation. Such non-technological innovation activity is often related to process, organizational, marketing, brand or design innovation, technical specifications, employee training, or logistics and distribution (see Figure 1.1, left column, and Subsection 1.2.4).

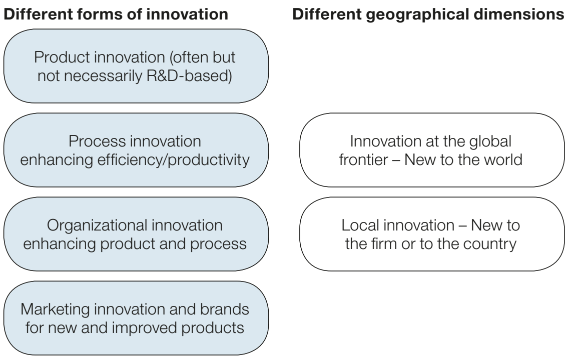
There is also greater interest in understanding how innovation takes place in low- and middle-income countries, noting that incremental forms of innovation can impact on development. This evolution in thought also recognizes that existing notions of innovation are too focused on frontier technologies and original innovation. While innovation can take place at the global frontier, local innovation that is new to a firm or a country can be equally important (see Figure 1.1, right column).

Second, the process of innovation has undergone significant change. As part of a new innovation paradigm, investment in innovation-related activity has consistently intensified at the firm, country and global level, both in terms of levels and shares of other investment, adding new innovation actors from outside high-income economies. This shift has also led to a much more complex structure of knowledge production activity, with innovative activity more dispersed geographically and collaboration on the rise, often in response to technological complexity.

26 See Fagerberg *et al.* (2010).
27 See David and Foray (2002).

Figure 1.1: Innovation takes different forms and has different geographical dimensions

Types of Innovation



Some of the numerous drivers for this gradually shifting innovation landscape are well-known:

- economies have become more knowledge-based as more countries enter the innovation-driven stage of development;
- globalization has led to new markets for innovative products as well as new production locations for them – Asia being the prime example of both;
- information and communication technologies (ICTs) have become diffused across industries and countries and have led to a fall in the cost of codifying, managing and sharing data and knowledge;
- the falling cost of travel has encouraged greater mobility; and
- the rise of common technology standards and platforms tied to de facto or industry standards – creating new innovation ecosystems on the one hand, and technological convergence on the other hand – has increased the ability to fragment innovation processes as well as the complexity of innovation.

The next subsections show that changes in the innovation landscape have happened more gradually and subtly over time than is often claimed. Trends that are often discussed, such as the increasing internationalization of innovation or wider "open" collaboration, are compared with official statistics, which time and again paint a more nuanced view. For instance, over the past two decades innovative activity has become more and more internationalized. Still, despite the shift in geographical composition of global science and technology production, R&D activity remains concentrated in only a few economies.[28]

For reasons of data availability (see Box 1.2), the next sections focus on innovation measured by quantifying knowledge and R&D inputs. However, innovation and related processes vary widely depending on the industry sector in question (see Chapter 2). The development of new drugs in the pharmaceutical sector, for instance, involves other levels and types of R&D investment and innovation activity than is the case in other sectors. This sectoral heterogeneity has to be kept in mind when studying the various degrees of collaboration, globalization and the use of IP at the aggregate level.

28 See Tether and Tajar (2008) and UNESCO (2010).

Box 1.2: Measuring innovation remains challenging

Direct official measures that quantify innovation output are extremely scarce. For example, there are no official statistics on the amount of innovative activity – as defined as the number of new products, processes, or other innovations (see Section 1.1) – for any given innovation actor or, let alone, any given country. This is particularly true when broadening the notion of innovation to include non-technological or local types of innovation. Most existing measures also struggle to appropriately capture the innovation output of a wider spectrum of innovation actors as mentioned above, for example the services sector, public entities, etc.

In the absence of such innovation metrics, science and technology (S&T) indicators or IP statistics have been used in the past as an approximate measure of innovation. These most commonly include data on R&D expenditure, R&D personnel, scientific and technical journal articles, patent-related data, and data on high-technology exports. Even these data are available for many but not all countries.[29] Moreover, these S&T indicators provide, at best, information on innovation input and throughput such as R&D expenditure, number of scientists, intermediate innovation output such as scientific publications or patents, or certain forms of technology-related commercial activity such as data on high-technology exports, or data on royalty and license fees.

In recent years the generation of data from so-called firm-level innovation surveys has improved the situation. Innovation surveys started with the European Community Innovation Survey (CIS) in the early 1990s, and are now being conducted in about 50-60 countries – mostly in Europe but also in a number of Latin American, Asian, African and other countries including, more recently, the US.[30] These surveys are a rich data source for analytical work. However, a number of problems exist: (i) innovation outside the business sector is not captured in these enterprise surveys; (ii) the quality of responses varies greatly and respondents have a tendency to overrate their innovative activity; (iii) country coverage is still limited; and (iv) survey results can only be compared to a limited extent across years and countries.

1.2.1

Globalization of production and demand for innovation

The way research and production activities are organized has changed over the last two decades. This can be partly attributed to greater integration and structural changes in the global economy; the emergence of new actors; and the ability of global firms to source scientific capabilities in different locations. The demand for innovative products and processes has also become internationalized.

Structural changes in the global economy: greater integration

Increasingly, multinational enterprises (MNEs) source input and technology from suppliers worldwide. This reflects a fragmentation of the production process in the manufacturing and services industries, with increases in task-based manufacturing, intermediate trade and outsourcing of services. As a result, a greater number of countries participate in global production and innovation networks.[31] Innovation networks have created a potential for technological and organizational learning by manufacturers and exporters, leading to industrial upgrading.[32]

29 In terms of availability, even seemingly straightforward indicators are scarcely available for more than a third of WIPO Member States. As an example, of the 214 territories/countries covered by the UNESCO Institute for Statistics, data for Gross Domestic Expenditure on Research and Development (GERD) in 2007 were only available for about 64 countries (mostly OECD or other high-income countries). For lower-income countries, these data are either unavailable or outdated (for example, for Algeria from 2005). No data are available for least developed countries (LDCs). There are typically even fewer data available for the other above-mentioned indicators. For instance, about 56 countries reported total R&D personnel for 2006.

30 Firm-level innovation surveys seek to identify the characteristics of innovative enterprise activity. After inviting firms to answer certain basic questions (on industry affiliation, turnover, R&D spending), firms were asked to identify whether they are an "innovator" and, if so, firms are asked to respond to questions regarding specific aspects of their innovation, as well as the factors that hamper their innovation. Finally, these surveys aim to assess the effect of innovation on sales, productivity, employment and other related factors.

31 For a recent overview and study, see Ivarsson and Alvstam (2010).

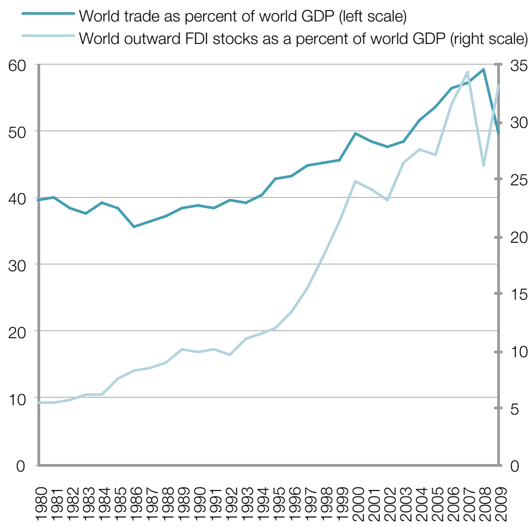
32 See UNIDO (2009).

The extent of economic integration is best exemplified in Figure 1.2 (top) which shows that world trade as percentage of GDP increased from about 40 percent in 1980 to about 50 percent in 2009; and world FDI outward stocks rose from 5.4 percent of world GDP in 1980 to about 33 percent in 2009. FDI inflows alone are expected to reach more than USD 1.5 trillion in 2011, with developing and transition countries, as defined by the United Nations (UN), now attracting more than half of FDI flows.[33] The foreign affiliates' share of global GDP has now reached a high point of about ten percent.[34] However, FDI flows to the poorest regions continue to fall.[35]

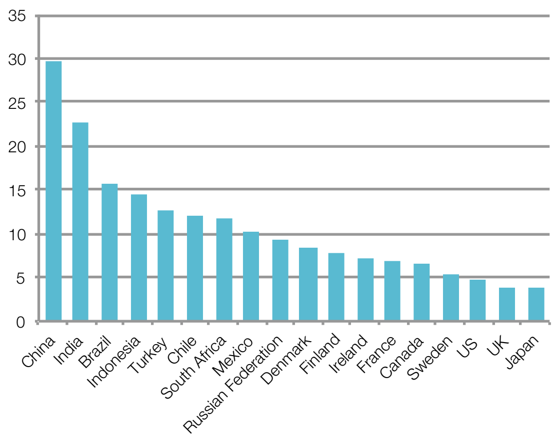
In parallel, a shift in manufacturing capacity from high-income to lower-income economies, in particular to Asia, has taken place. This shift is primarily linked to the fact that products are increasingly assembled outside of high-income economies.[36] Mirroring this trend, the share of high-technology exports of the US and Japan has constantly decreased – from 21 percent in 1995 to 14 percent in 2008 for the US, and from 18 percent in 1995 to eight percent in 2008 in the case of Japan – with the share of Europe remaining constant. In contrast, China's share increased from six percent in 1995 to 20 percent in 2008, with other economies such as Mexico and the Republic of Korea also constantly increasing their shares. In terms of the growth of high- and medium-high-technology exports, China, India, Brazil and Indonesia are in the lead (see Figure 1.2, bottom).

Figure 1.2: Economic integration and the fragmentation of value chains have been on the increase

World trade and outward FDI stocks, as a percentage of world GDP, 1980-2009



Growth of high- and medium-high-technology exports, average annual growth rate, in percent, 1998-2008



Note: In the bottom figure, data refer to 2000-08 for Brazil, Indonesia, India, China and South Africa. The underlying data for China include exports to China, Hong Kong.

Source: WIPO, based on data from the World Bank, UN Comtrade and UNCTADstat, September 2011.

33 See UNCTAD (2011).
34 *Idem.*
35 *Idem.*
36 For a discussion on the ICT industry value chain, see Wunsch-Vincent (2006).

Furthermore, the output of knowledge- and technology-intensive industries (KTI) is also increasing and becoming more geographically diffuse.[37] In particular, the global output of knowledge- and technology-intensive industries as a share of global GDP increased to close to 30 percent of global GDP in 2007, with knowledge-intensive services accounting for the greatest share at 26 percent, and high-technology manufacturing industries accounting for 4 percent. ICT industries, composed of several KTI as defined above service and high-technology manufacturing industries, accounted for seven percent of global GDP in 2007. The share is greatest in countries such as the US (38 percent), the European Union (EU) (30 percent) and Japan (28 percent). Other countries, such as China (23 percent) or regions in Africa (19 percent), have also increased their knowledge- and technology-intensive industry output as a share of GDP.

Structural changes in the global economy: more balanced world income and demand for innovation

Firms and citizens in particular middle-income economies have not only emerged as substantial contributors to technology production, but have also created significant demand for products and innovation themselves.

For the first time since the 1970s, the last decade saw a trend towards convergence in per capita income.[38] The number of converging economies increased rapidly, with growth being strongest in a few large middle-income economies but with growth also increasing more generally in, for example, Africa – averaging 4.4 percent growth between 2000 and 2007. Whereas in 1980, about 70 percent of world GDP (measured in purchasing power parities, PPP) was concentrated in high-income countries, that share fell to 56 percent in 2009, with the share of upper middle-income economies making up for the biggest increase – from about 22 percent to about 31 percent – and the low-income country group increasing only marginally (see Figure 1.3, at top). This partial convergence has been spurred further by the economic crisis, with GDP growth holding up more strongly outside of high-income economies.

37 National Science Board (2010). These data are based on calculations by the National Science Foundation following the OECD's classification of knowledge-intensive service and high-technology manufacturing industries and data provided by IHS Global Insight. The OECD has identified 10 categories of service and manufacturing industries—collectively referred to as KTI industries—that have a particularly strong link to science and technology. Five knowledge-intensive service industries incorporate high technologies either in their services or in the delivery of their services. They include financial, business, and communications services (including computer software development and R&D), which are generally commercially traded. They also include education and health services, which are primarily government provided and location bound. The five high-technology manufacturing industries include aerospace, pharmaceuticals, computers and office machinery, communications equipment, and scientific (medical, precision, and optical) instruments.

38 OECD (2010e).

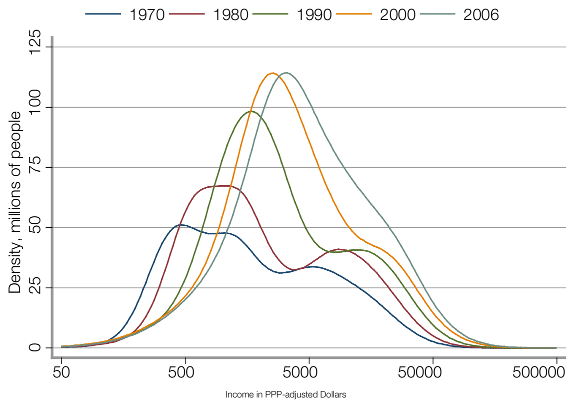
Combined with greater population growth in lower-income countries, world distribution of income has progressively shifted. Figure 1.3 (at bottom) shows that between 1970 and 2006, the absolute level and the distribution of world income have progressively increase, with more millions of people benefiting from higher incomes. Per capita income has risen, increasing household final expenditure substantially during the last decades and contributing to greater demand for innovation. Specifically, in 2009 the average per capita income in high-income economies was roughly 14 times that of a middle-income economy – compared to roughly 20 times in 1990 and 2000.

Moreover, two to three billion people are projected to enter the middle class in the coming decades. This will constitute a new source of demand for goods and services tailored to the specific needs of this middle class emerging in less developed economies. Adapting products to emerging markets will henceforth be a core activity of MNEs, including for households with fewer resources that will demand low prices for robust products with basic functionality.[39]

Figure 1.3: World income distribution is becoming more equalized

Distribution of world GDP by income group, as a percentage of total GDP, current PPP – dollar

Distribution of world income by density (millions of people per income group), current PPP – dollar



Note: In the top graph the GDP comparisons are made using PPPs.

Source: WIPO, based on data from the World Bank (top), October 2011 and Pinkovskiy and Sala-i-Martin (2009) (bottom).

At the same time, the gap between high-income and low-income economies has increased. In particular, the income in the richest countries equaled 84 times the low-income average GDP per capita in 1990, 81 times in 2009, but only 55 times in 1974. How innovation occurs and is diffused to these countries despite this rising income gap is a matter of concern.

39 See Prahalad and Lieberthal (1998) and the literature building on this contribution.

1.2.2

Increased investment in innovation

Investment in knowledge now makes up a significant share of GDP for most high-income and rapidly growing economies. Such investment concerns expenditure on R&D, private and public education and software.[40] These data are not yet available for low-income economies.

Israel, the Republic of Korea, the US, and the Nordic countries have the highest levels of investment in knowledge per GDP in 2008 (see Figure 1.4).[41] In terms of growth, Argentina, Brazil, Romania and Uruguay recorded double-digit growth from 2003 to 2008 with values for China unavailable for 2003. The following high-income economies have increased investment in knowledge most rapidly in the same time period: Ireland, the Czech Republic and the Republic of Korea. Investment in knowledge as a percentage of GDP declined in a number of countries – Malaysia, India, Hungary and Chile – in part due to faster GDP growth rates.

For all reported countries, education accounted for the largest share of total investment in knowledge – more than half in all cases. It accounted for more than 80 percent of total investment in knowledge for a large number of middle-income economies, including Argentina, Bolivia, Chile, Colombia, Peru, Mexico, Morocco, Thailand, and Tunisia.

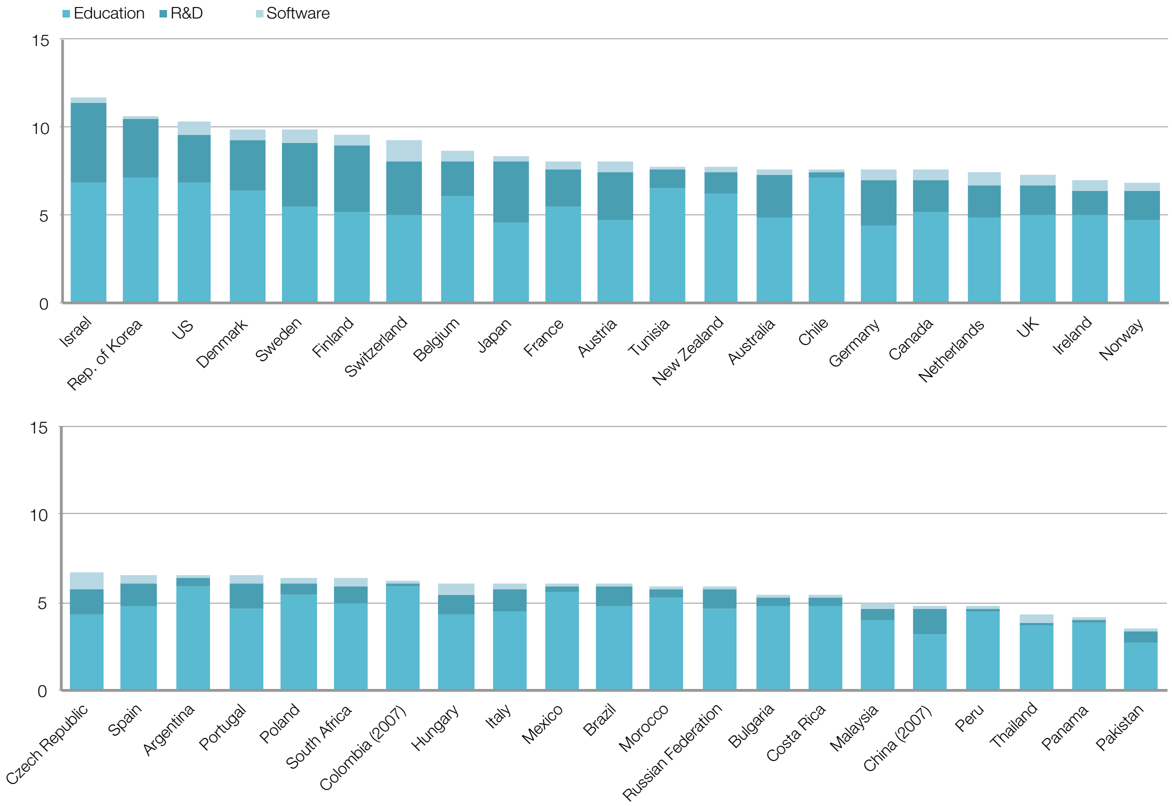
With regard to R&D expenditure, however, outside, China, only high-income economies devote to investments in R&D a share larger than 20 percent of total investment in knowledge. The share of R&D in total investment in knowledge is more than a third for Japan, Israel, Finland, Sweden, Germany and Austria in 2008, with high-income countries investing anywhere between 1 percent of GDP to R&D (Hungary) to 4.7 percent (Israel). For the majority of countries, the share of R&D in total knowledge investment increased, albeit only marginally, between 2003 and 2008.

40 Investment in knowledge is defined and calculated as the sum of expenditure on R&D, total education (public and private for all levels of education) and software. Simple summation of the three components would lead to an overestimation of investment in knowledge owing to overlaps (R&D and software, R&D and education, software and education). Data reported here have been adjusted to exclude these overlaps between components. See Khan (2005).

41 When making comparisons with regard to R&D or other knowledge-investment intensity, it makes sense to avoid direct comparisons between smaller and larger economies.

Figure 1.4: Countries are investing in knowledge

Investment in knowledge, as a percentage of GDP, 2008 or latest available year, selected countries



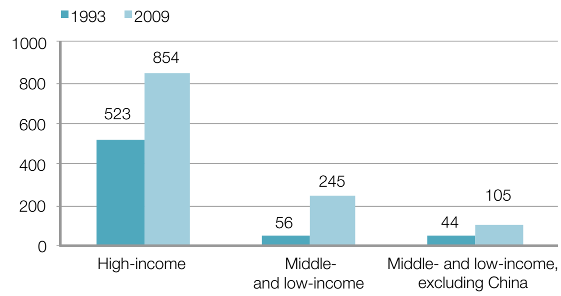
Note: For China, education expenditure refers to public expenditure only. When making comparisons to R&D-intensity it makes sense to divide countries into smaller and larger economies. R&D -intensity for small economies is often determined by one or a few companies.

Source: WIPO, based on data from UNESCO Institute for Statistics, Eurostat, OECD, World Bank and the World Information Technology and Services Alliances, September 2011.

In 2009, about USD 1.2 trillion (constant PPP 2005 USD) was spent on global R&D. This is roughly the double spent in 1993 at USD 623 billion. However, worldwide R&D spending is skewed towards high-income countries (see Figure 1.5), which still account for around 70 percent of the world total. This holds true despite the fact that their share dropped by 13 percentage points between 1993 and 2009. The share of middle- and low-income countries more than doubled between 1993 and 2008; however, almost all the increase in the world GDP share is due to China, which is now the second largest R&D spender in the world.

Figure 1.5: R&D expenditure still comes mainly from high-income countries

Worldwide R&D expenditure, by income group, in 2005 PPP Dollars, 1993 and 2009



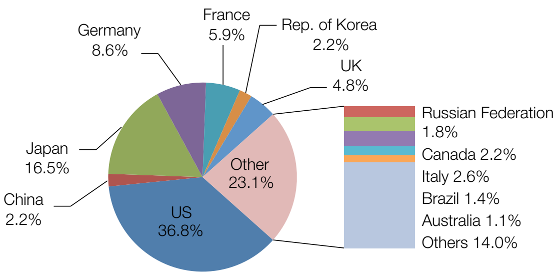
Note: R&D data refer to gross domestic expenditure on R&D (GERD). The high-income group includes 39 countries, and the middle- and low-income group includes 40 countries.

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

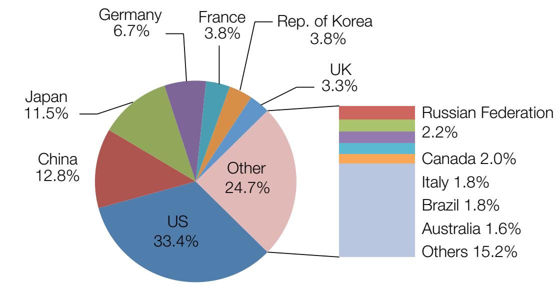
Between 1993 and 2009, the share of major spenders from the US, Canada, and all European countries declined, while the share of Brazil, China, the Republic of Korea, and countries such as the Russian Federation increased (see Figure 1.6). China is still the only middle-income country, however, that has emerged as a major R&D spender.

Figure 1.6: China has emerged as major R&D spender

Country shares in world R&D, in percent, 1993



Country shares in world R&D, in percent, 2009



Note: R&D data refer to gross domestic expenditure on R&D (GERD).

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

In countries with the largest R&D expenditure, the business sector has persistently increased its share. Firms now account for the bulk of total R&D performance in these economies. In high-income countries, the share of business R&D in total R&D is around 70 percent while shares in Israel reach 80 percent, and around 75 percent in Japan and the Republic of Korea (see Figure 4.1 in Chapter 4).[42] Due to rapid growth in China, the local share of business R&D in total R&D is now similar to the US level, at around 73 percent. In a large number of Asian, Latin American and other middle- and low-income countries R&D is, however, still mainly conducted by the public sector (see Chapter 4).

New innovation actors have also emerged. For instance, the increase in contributions of philanthropic funds to the level and organization of R&D and innovation is a more recent phenomenon.

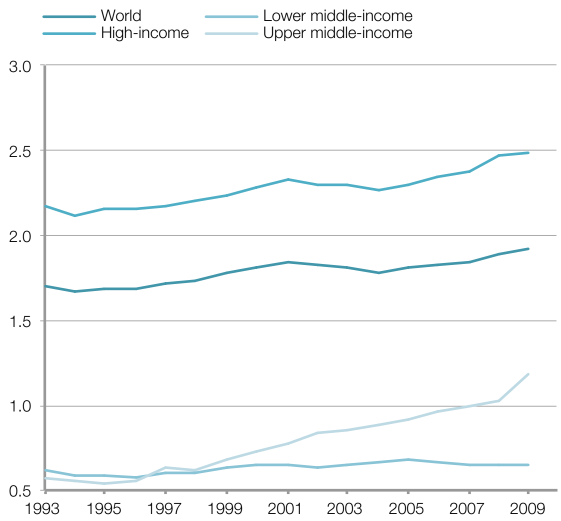
Despite rapid growth in R&D spending, the share of GDP devoted to R&D across the world, referred to as R&D-intensity, increased at a modest rate – from 1.7 percent in 1993 to 1.9 percent in 2009 (see Figure 1.7, top). However, there is considerable variation across income groups and countries. High-income economies spend around 2.5 percent of GDP on R&D activity, which is more about double the rate of the upper-middle-income groups. The sharp growth in R&D-intensity for the upper-middle-income group is mostly due to China.

R&D-intensity was highest for Israel, Finland and Sweden (see Figure 1.7, bottom). Australia, China, Finland, and the Republic of Korea are among the countries that have strongly increased R&D-intensity.

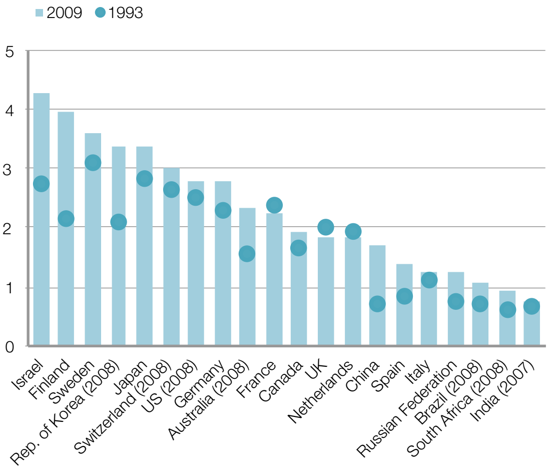
42 OECD, Main Science and Technology Indicators database (MSTI), May 2010.

Figure 1.7: R&D-intensity has increased, sometimes at a modest rate

R&D-Intensity, by income group, in percent, 1993-2009



R&D-Intensity, in percent, selected countries, 1993 and 2009



Note: R&D data refers to gross domestic expenditure on research and development. World total is based on 79 countries. High-income, upper middle-income and lower middle-income group consists of 39, 27 and ten countries respectively. R&D intensity is defined as R&D expenditure over GDP.

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

Finally, the share of software in total investment in knowledge is less than ten percent in the majority of countries (see Figure 1.4). Middle-income economies, many of which are located in Latin America, invest disproportionally in software, in order to catch up to levels similar to those in high-income economies.

1.2.3

INTERNATIONALIZATION OF SCIENCE AND INNOVATION

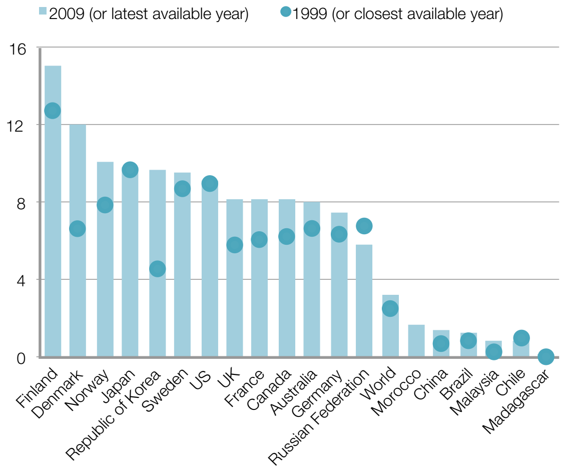
Increasing internationalization of science

Scientific research is becoming increasingly interconnected, with international collaboration on the rise. The increased importance attached to innovative activity is reflected in the growing number of researchers. In terms of worldwide distribution, the proportion of researchers in China increased from 12.3 percent in 1997 to 22.7 percent in 2008. For other major countries – the US, Japan and the Russian Federation – the share in the total has followed a downward trend.

In 2008, the average number of researchers per thousand labor force across the world was around 3.2, a considerable increase from 2.6 in 1999. In terms of researchers per labor force, the Scandinavian countries rank first, followed by Japan and the Republic of Korea (see Figure 1.8). In absolute terms, China has the largest pool of researchers but, relative to its labor force, the numbers are still small in comparison to high-income countries and the world average. Between 1999 and 2009, most countries increased the number of their researchers. The Russian Federation and Chile however experienced a drop in researcher intensity.

Figure 1.8: The number of researchers is growing in a larger number of countries

Researchers per 1,000 labor force, 1999 and 2009, or latest available



Note: Researchers data refer to full time equivalents. The world total is based on figures from 78 countries.

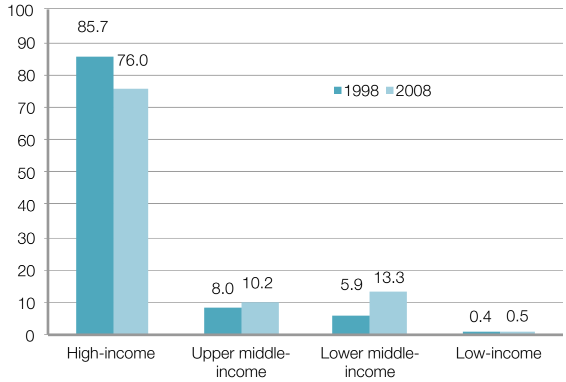
Source: WIPO based on data from UNESCO Institute for Statistics, Eurostat and OECD, September 2011.

This internationalization of skills is also mirrored in data showing the growing number of science and engineering graduates from countries such as China and India.[43] The increase in number of researchers and the S&T workforce has been accompanied by an increased mobility of students, highly-skilled workers and scientists in particular, positively influencing the international transfer of knowledge.[44]

In terms of internationalization of science, the last decades have seen a significant increase in worldwide scientific publications, to about 1.5 million peer-reviewed science and engineering articles in 2008 produced by 218 countries – up from less than one million publications in 2000.[45] Although scientific production is still far from the level in high-income economies, publication activity is increasing in middle-income economies (see Figure 1.9). This is again largely driven by a few economies such as India and China.

Figure 1.9: Science is becoming internationalized

Share of the world total of scientific and technical journal articles, by income group, in percent of total, 1998 and 2008



Source: WIPO, based on data by Thomson in National Science Board (2010).[46]

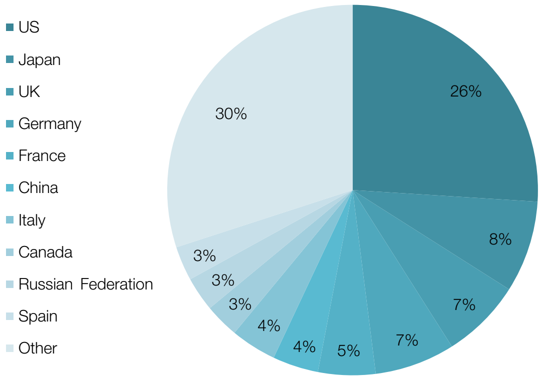
As a result, the sources of global scientific publications are changing (see Figure 1.10). The decreasing proportion of publications from the US, Japan, Germany, France and other leading high-income economies is most noteworthy. At the same time, China and India have risen to the fore, with, respectively, ten and two percent of publications in the period 2004-2008. Brazil, Malaysia, Singapore, The Republic of Korea, Thailand and Turkey also account for rising world shares of scientific publications.

Nonetheless, despite growth in journal contributions from other countries, scientific articles from high-income countries continue to attract the majority of citations.[47]

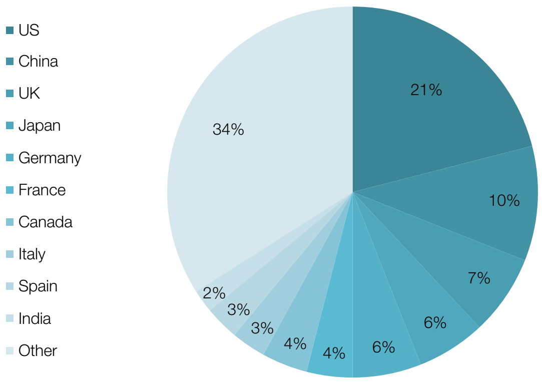
43 Based on data from UNESCO.
44 See Edler *et al.* (2011); and Filatotchev *et al.* (2011) on the positive effects of labor mobility on international knowledge spillovers.
45 See Royal Society (March 2011). Data based on Elsevier's Scopus database.
46 At *www.nsf.gov/statistics/seind10/append/c5/at05-25.xls*.
47 See Royal Society (March 2011).

Figure 1.10: Sources of global scientific publications are changing

Proportion of global publications, by country, in percent of total, 1993-2003



Proportion of global publications, by country, in percent of total, 2004-2008



Source: WIPO, based on data from Elsevier Scopus provided in Royal Society (2011).

Business R&D is becoming internationalized

Most international R&D investment is still confined to high-income economies, both in terms of investing and receiving economies. Furthermore, the largest cross-border flows of R&D continue to occur among the US, the EU and Japan. In the US, France and Germany, foreign affiliates of MNEs account for between 15 and 26 percent of total business manufacturing R&D. This figure reaches 35 percent in the UK, and more than 60-70 percent in Austria and Ireland.[48]

Attracted by rapidly expanding markets and the availability of lower-cost researchers and facilities, leading multinationals have nonetheless increased their R&D beyond high-income countries, in particular in large middle-income economies. The share of foreign affiliates in local R&D is higher in large middle-income countries such as China and Brazil than in high-income economies.[49]

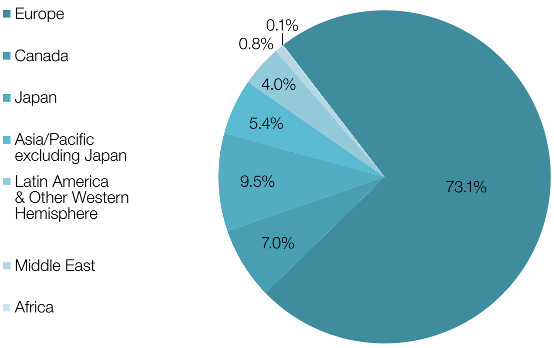
The available evidence points to an increase in overseas R&D out of total R&D expenditure by MNEs, with a focus on a few centers of excellence. Annual overseas R&D expenditure by US MNEs, for instance, increased rapidly from almost USD 600 million in 1966 to around USD 28.5 billion in 2006.[50] High-income countries are by far the dominant location of R&D activity by US MNEs, accounting for about 80 percent of total overseas R&D expenditure (see Figure 1.11). Increases in R&D shares have occurred primarily in some high-performing East Asian economies, in particular China, Malaysia, the Republic of Korea, and Singapore. Nonetheless, they still stand at relatively modest levels, with China at about three percent and India about one percent of total overseas R&D by US MNEs.

The internationalization of business R&D is also concentrated in a few sectors. The following industries account for the bulk in US affiliates' overseas R&D: transportation equipment, including the car industry, at 29 percent of overseas R&D; chemicals, including pharmaceuticals, at 22 percent; and computer and electronic products, including software publishers, at 17 percent.[51]

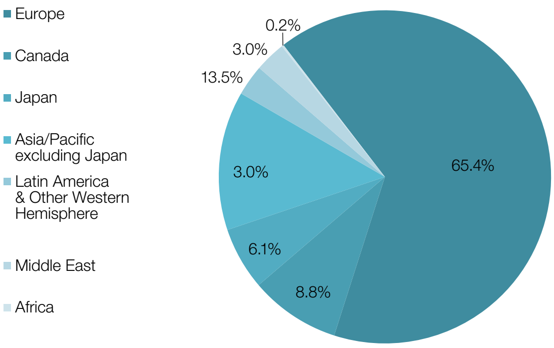
48 OECD MSTI, June 2011.
49 See OECD (2010e) and Nolan (2009). In 2003, the share of foreign affiliates in total R&D was 24 percent in China, 48 percent in Brazil, 47 percent in the Czech Republic and 63 percent in Hungary.
50 At *www.nsf.gov/statistics/seind10/c4/c4s6.htm* and *www.bea.gov/scb/pdf/2010/08 percent20August/0810_mncs.pdf*.
51 See National Science Board (2010).

Figure 1.11: High-income countries are by far the dominant location of R&D activity

Regional shares of R&D conducted abroad by foreign affiliates of US MNEs, in percent of total, 1994



Regional shares of R&D conducted abroad by foreign affiliates of US MNEs, in percent of total, 2006



Note: Regions as defined by the US National Science Foundation.
Source: WIPO, based on data from the US Bureau of Economic Analysis and the US National Science Foundation.

The role of multinationals of middle-income economies in local innovation

MNEs from fast-growing middle-income economies have emerged as their revenues and innovation capacity become more similar to firms in high-income countries.

There were around 23,000 MNEs in middle- and low-income countries in 2009. This represents 28 percent of the total number of MNEs, compared to less than ten percent of firms in the early 1990s.[52] The number of firms from middle- and low-income economies that appear in company rankings by revenue, such as the Financial Times (FT) 500, has risen markedly.[53] Specifically, China has gone from zero firms in 2006 to 27 firms in 2011; Brazil from six to eleven; the Russian Federation from six to eleven; and India from eight to 14 firms in the 2011 FT500 ranking. In 2011, there were a total of 83 firms in the FT500 from middle-income countries, representing about 17.5 percent of total market capitalization, compared to 32 firms with 4.5 percent market capitalization in 2006.

Data on the top 1,000 global R&D spenders confirm that a number of multinationals from middle-income economies now conduct substantial R&D on a par with R&D-intensive multinationals of high-income countries (see Table 1.1). These MNEs come from a handful of countries only, notably China, with five firms in 2005 compared to 15 in 2009; and India, with two firms in 2005 compared to four in 2009. R&D-intensity is, however, still low. Whereas R&D expenditure over sales by US firms in the top 1,000 R&D spenders is about 4.5 percent, the average R&D-intensity of top Chinese R&D spenders included in this ranking is lower, also reflecting the sectoral affiliation of Chinese top R&D spenders.

52 See UNCTAD (2010).
53 The FT500 rankings can be gleaned from *www.ft.com/reports/ft-500-2011*.

FDI outflows from firms other than those in high-income economies are also growing, and stand at about 29 percent of total FDI in 2010. This is mainly driven by Chile, China, Egypt, Malaysia, Mexico, the Russian Federation, South Africa, Thailand and Turkey.[54] In 2010, six developing and transition economies – as defined by the UN – were among the top 20 investors. Flows of outward FDI from lower- or middle-income economies rose from about USD 6 billion in 1990 to USD 388 billion in 2010, about 29 percent of total outward flows.[55] These outward investments guarantee proximity to high-income markets and advanced innovation systems which can be exploited by cooperating with local suppliers, customers, universities and other actors.

Once more, this FDI outflow and related knowledge flows are still limited to a small group of economies with a relatively well-developed knowledge infrastructure. Apart from the rise in outward investment by China and the Russian Federation, no other low- or middle-income country has recently emerged as a significant outward FDI investor. Brazil, South Africa, India and fast-growing South-Asian economies were already outward investors by the 1980s.[56] If one eliminates a number of fast-growing middle-income countries, the percentage of outward FDI from lower- or middle-income countries as a share of global outward FDI declines to around 2.4 percent for the period 1993-2007.[57]

In relation to the growing innovation capacity of MNEs of less developed countries, discussions have recently focused on new concepts such as “frugal”, “reverse” or “trickle-up” innovation. These types of innovation focus on needs and requirements for low-cost products in lower-income countries. At times, these new products or processes can also succeed in penetrating markets in high-income economies.[58] Local firms reinvent systems of production and distribution in the process, and also experiment with new business models while leveraging their familiarity with local customer needs.[59] Examples cited in this context include: the activities of Indian ICT providers in the software outsourcing market; the development by Indian firm Tata Motors of a car costing USD 2,000; and the sale by GE on the US market of an ultra-portable electrocardiograph machine originally built by GE Healthcare for doctors in India and China.

Analysis of this potential new development must move beyond anecdotal examples to better enable economists and policymakers to gauge its true economic ramifications.

54 See UNCTAD (2011).
55 See Athreye and Kapur (2009).
56 See Narula (2010).
57 *Idem*.
58 See Prahalad and Lieberthal (1998).
59 See, for instance, Ray and Ray (2010).

Table 1.1: Top R&D spenders from fast-growing middle-income countries, rank out of top 1,000 global R&D spenders, 2009

Rank	Name	Country	Industry Group	2009 R&D expenditure (USD, constant exchange rate)	Average R&D-intensity (2004-2009)	R&D-intensity (2009)
77	PetroChina Co Ltd	China	Oil & Gas	1,447	0.7%	1.0%
102	Vale SA	Brazil	Mining	996	2.5%	4.0%
123	ZTE Corp	China	Telecommunications	846	9.8%	9.6%
139	China Railway Construction Corp Ltd	China	Engineering & Construction	756	0.8%	1.5%
150	Petroleo Brasileiro SA	Brazil	Oil & Gas	690	0.8%	0.7%
186	China Petroleum & Chemical Corp	China	Oil & Gas	559	0.3%	0.3%
244	A-Power Energy Generation Systems Ltd	China	Electrical Components & Equipment	381	104.4%	122.3%
280	Dongfeng Motor Group Co Ltd	China	Auto Manufacturers	305	2.0%	2.3%
324	China Communications Construction	China	Engineering & Construction	254	0.4%	0.8%
330	China South Locomotive and Rolling Stock Corp	China	Machinery-Diversified	246	2.4%	3.7%
355	Lenovo Group Ltd	China	Computers	214	1.4%	1.3%
357	Metallurgical Corp of China Ltd	China	Engineering & Construction	212	0.6%	0.9%
401	Byd Co Ltd	China	Auto Manufacturers	188	3.1%	3.3%
426	Tencent Holdings Ltd	China	Internet	174	8.9%	9.6%
445	Shanghai Electric Group Co Ltd	China	Machinery-Diversified	162	1.2%	1.9%
446	Semiconductor Manufacturing International Corp	China	Semiconductors	161	7.7%	15.0%
517	Shanghai Zhenhua Heavy Industry	China	Machinery-Diversified	137	1.5%	3.4%
523	China CNR Corp Ltd	China	Machinery-Diversified	136	1.9%	2.3%
627	Tata Motors Ltd	India	Auto Manufacturers	105	0.4%	0.5%
683	China Railway Group Ltd	China	Engineering & Construction	95	0.2%	0.2%
696	Dongfang Electric Corp Ltd	China	Electrical Components & Equipment	93	1.8%	1.9%
699	Infosys Technologies Ltd	India	Computers	92	1.4%	1.9%
788	CPFL Energia SA	Brazil	Electric	79	0.8%	1.5%
799	Dr Reddys Laboratories Ltd	India	Pharmaceuticals	78	6.3%	5.3%
819	Lupin Ltd	India	Pharmaceuticals	75	6.6%	7.5%
846	Empresa Brasileira de Aeronautica	Brazil	Aerospace & Defense	73	1.7%	1.3%
848	Reliance Industries Ltd	India	Oil & Gas	73	0.2%	0.2%
849	Sun Pharmaceutical Industries Ltd	India	Pharmaceuticals	73	8.7%	7.8%
906	Harbin Power Equipment Co Ltd	China	Electrical Components & Equipment	68	1.6%	1.6%
921	China National Materials Co Ltd	China	Machinery & Construction & Mining	67	0.7%	1.5%
925	Weichai Power Co Ltd	China	Auto Parts & Equipment	66	1.3%	1.3%
968	Baidu Inc/China	China	Internet	62	9.0%	9.5%
976	Shanda Interactive Entertainment Ltd	China	Internet	61	7.8%	8.0%
992	Totvs SA	Brazil	Software	60	10.7%	12.0%

Note: R&D intensity as defined by R&D over revenues. The database only contains publicly-listed companies.
Large R&D spenders such as Huawei (China telecommunications) which have similarly large R&D budgets are thus not included.

Source: WIPO, based on Booz & Company Global Innovation 1,000 database.

1.2.4

The importance of non-R&D-based innovation

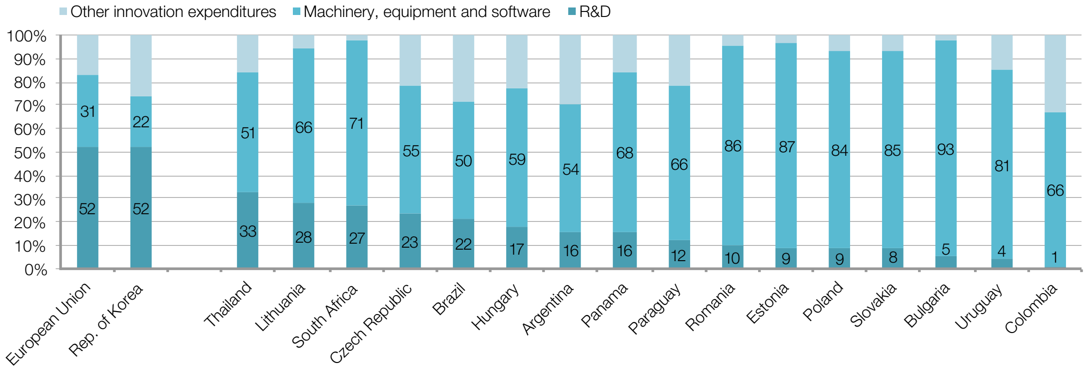
As described at the outset, the rise and globalization of R&D is not the only characteristic of the new innovation landscape. Innovation not based on R&D, including non-technological innovation, is increasingly perceived as an important contributor to economic growth and development. The service sector in particular has increased its efficiency by reorganizing business processes, in part facilitated by ICTs.

Specifically, innovation surveys find that a large share of innovative firms do not conduct any formal R&D. Specifically, almost half of innovative firms in Europe do not carry out R&D in-house.[60] Moreover, data from innovation surveys show that non-R&D innovators are relatively more prevalent in low-technology manufacturing and the service industries. Sectors with low R&D-intensity, such as textiles, clothing and paper, can be as likely to innovate as high-tech industries.[61] Surveys also find that it is small and medium-sized firms in particular which innovate without conducting formal R&D.

In the case of middle- or low-income economies, innovation expenditure by firms from the manufacturing sector often concerns machinery and equipment or related expenditure, rather than R&D (see Figure 1.12). Innovation is much more incremental. Whereas in the European Union (EU)-15, firms claim that new machinery and equipment is only responsible for about 22 percent of their innovation expenditure, in economies such as Bulgaria, Colombia, Paraguay, South Africa and Uruguay this figure can exceed 60 percent of total innovation expenditures. In these countries, investment in physical assets can increase productivity and lead to valuable organizational innovation.

Figure 1.12: Firms in middle- and lower-income countries invest in machinery and equipment to innovate

Distribution of innovation expenditure by firms in manufacturing industries, in percent of total, 2008 or last available year, selected countries



Note: Indicators refer to the manufacturing industry except for South Africa and Thailand whose indicators reported refer to manufacturing and services industries. The indicator for the European Union-15 is the average share across countries.[62]

Source: Zuñiga (2011) based on innovation Surveys.[63]

60 See the Third Community Innovation Survey.

61 See, for instance, Mendonça (2009) and the other papers in this special issue of Research Policy on Innovation in Low- and Medium-technology Industries.

62 The EU-15 figures include Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Data for Austria and Italy which are normally EU-15 is not available.

63 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).

Beyond the non-R&D innovation expenditure discussed above, research suggests that process and organizational innovation can be a prominent driver of improved firm performance. In fact, this is perhaps the most important form of non-technological innovation, particularly in the service sector.[64] Furthermore, the introduction of innovative and new technologies frequently requires enhanced skills as well as complementary organizational changes in administration and structure. Technological and organizational innovation are thus often complementary.

Nevertheless, the existing economic literature acknowledges that measuring the positive contribution of process and organizational innovation to productivity is much harder (see Section 1.1).[65] One reason for the lack of evidence in this area is that the interactions between and complementary nature of technological and non-technological innovation are hard to measure and fully assess.

64 See, for instance, Evangelista and Vezzani (2010).

65 See Hall (2011).

1.2.5

Greater collaboration in the process of innovation

Innovation has always taken place in the context of institutional and other linkages between various innovation actors.

Yet another transformation in the much discussed new innovation paradigm is the increasingly collaborative nature of innovative processes. According to this view, firms increasingly seek valuable knowledge and skills beyond their own boundaries, in order to enlarge their capabilities and enhance their assets (see Chapter 3). Joint innovation activity involves formal cooperation modes such as R&D consortia, research ventures, IP-based forms of collaboration, co-production, co-marketing or more informal modes of cooperation. Lastly, collaboration also occurs between universities, public research organizations and firms (see Chapter 4).

Such collaboration has been facilitated as innovation processes and activity have become more easily fragmented. Moreover, the expansion of markets for technologies that allow for knowledge exchange via patent licenses and other IP-based forms of exchange have been a driver of collaboration.

Collaboration is at the heart of innovation, but measurement remains difficult

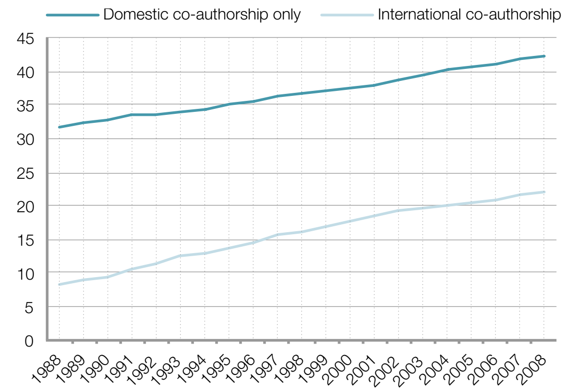
The statistics available for assessing frequency, type and impact of collaboration are limited. They are mostly based on data relating to R&D, publications, patents or innovation surveys, all of which have their limitations. A significant share of collaborative activity also remains unmeasured and/or is kept secret. Importantly, existing data say little about the quality dimension and impact of cooperation. As highlighted above, collaboration covers a wide field and involves different degrees of involvement, from sharing information through to conducting joint R&D and product development. Related impacts of cooperation might also materialize over time.

Despite these caveats, existing measures suggest that cooperation between firms and between firms and the public sector is increasing over time:

- **Increased cooperation on scientific publications:** About 22 percent of all peer-reviewed science and engineering articles in 2007 were published with international co-authorship, which is about three times higher than in 1988 (see Figure 1.13). About 42 percent of articles are co-authored domestically, up from about 32 percent in 1988.

Figure 1.13: International and domestic co-authorship are on the rise

Share of co-authored science and engineering articles, as a percentage of total global publications, 1988-2008



Source: WIPO, based on Thomson Reuters data in National Science Board (2010).

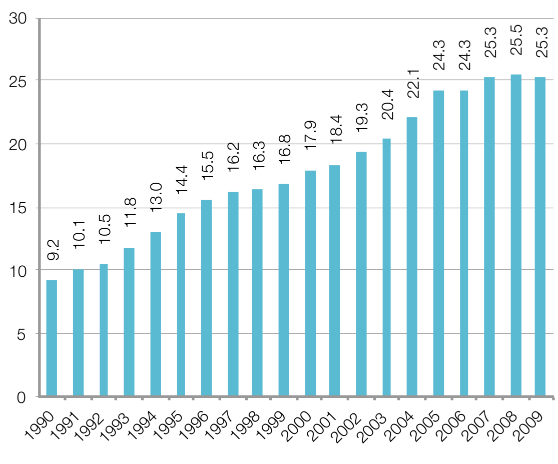
- **Prevalence of R&D partnerships in certain key sectors:** Empirical studies show that the number of R&D partnerships is particularly important in a number of industries, such as ICTs and biotechnology (see Chapter 3).[66]

- **Increased R&D outsourcing and contract research:** Outsourcing of R&D – either to other private or to public organizations such as universities – has also become an integral, albeit usually small, complement to in-house R&D. R&D contracted out by US manufacturing companies has, for instance, increased from 3.3 percent of total R&D in 1993 to 8.5 percent in 2007.[67] Data on companies that spend the most on R&D reveal that, on average, nine out of ten firms outsource 15 percent of their R&D.[68] Two-thirds of this outsourced R&D is conducted by other companies and one-third by public research organizations.[69]

- **Increased number of patent co-inventors:** An increasing number of inventors from diverse countries apply together for one and the same patent (see Figure 1.14 and Box 1.3).

Figure 1.14: International collaboration is increasing among inventors

Patent applications filed under the Patent Cooperation Treaty (PCT) with at least one foreign inventor, as a percentage of total PCT filings, 1990-2009



Note: The data reported above are based on published PCT applications.

Source: WIPO Statistical Database, July 2011.

66 See, for instance, the relevant work of John Hagedoorn on this issue at *www.merit.unu.edu/about/profile.php?id=26&stage=2*.
67 See National Science Board (2010). These figures include company-funded and company-performed R&D.
68 See OECD (2009).
69 Note that this study was only based on a non-representative sample of 59 companies.

Box 1.3: Caveats in the use of data on co-patenting as an indicator of international collaboration

Patent data showing the frequency of co-inventions, i.e., patents with several inventors listed as applicants, are frequently used to demonstrate that international collaboration among inventors is increasing.[70]

One of the advantages of patent data is their wide availability for many countries. One can use national patent data or data generated by the PCT System to showcase joint patent applicants with different national backgrounds.

To identify forms of "international" collaboration one assesses the nationality and/or residence of multiple inventors assigned to a particular patent. With increased global mobility and inventors with multiple or changed nationalities and residences, applying this procedure to identify true cross-border collaboration is not straightforward. If based solely on an inventor's nationality as shown in patent databases, the following circumstances, for instance, could lead to the erroneous conclusion that cross-border cooperation had occurred where it actually had not: intra-organizational collaboration between two inventors of different nationalities who are in the same location for the duration of the project; collaboration between two inventors who reside in two different countries but work in the same country; an inventor who moves to a different country after a project has ended with the new residence appearing on the patent due to formal administrative delays.

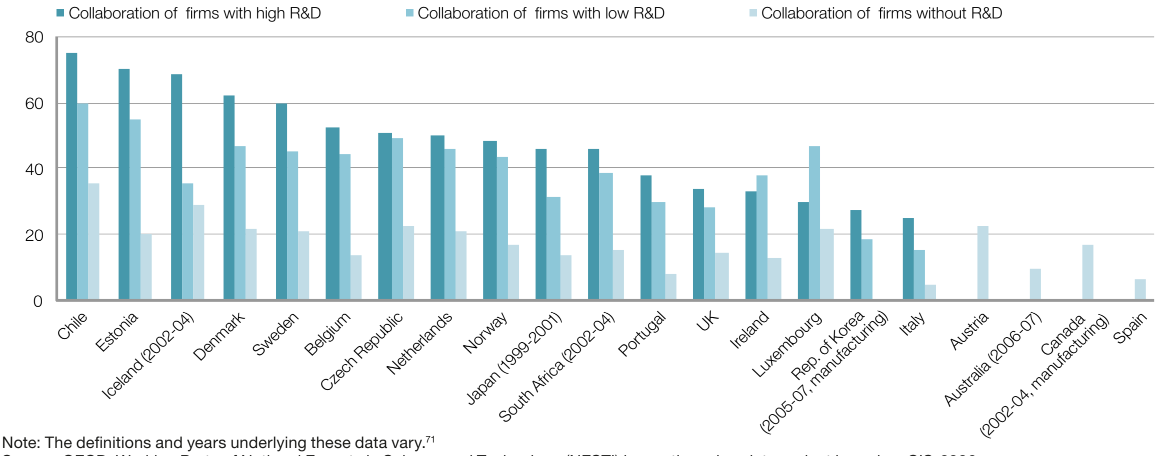
In a recent paper by Bergek and Bruzelius (2010), the relevance of considering patents with multiple inventors from different countries as an indicator of international R&D collaboration has thus been questioned. Focusing on Swiss energy and automation firm ABB, the study shows that half of this firm's patents which, according to existing methods, would be treated as if they were the result of international collaboration, are truly not. The other half would erroneously be qualified as "international collaboration" for the reasons listed above.

- Increased national and international collaboration in innovation: Innovation surveys show that more R&D-intensive firms collaborate more than those that conduct less R&D. In Chile, for instance, 74 percent of the most R&D-intensive innovative firms collaborate – defined as firms that innovate and have the highest ratio of R&D expenditure over sales – while only 60 percent of other R&D performers and only 35 percent of innovative firms that do not conduct R&D collaborate (see Figure 1.15). Collaboration in les developed economies tends to proceed on a different basis in such R&D constrained environments, such as the need to simply adapt products for local consumption. Surveys also show that the propensity to collaborate on innovation with partners abroad varies widely between countries (see Figure 1.16).

70 See, for instance, OECD (2010c) and WIPO (2010).

Figure 1.15: Increasing R&D expenditure and collaboration go hand in hand

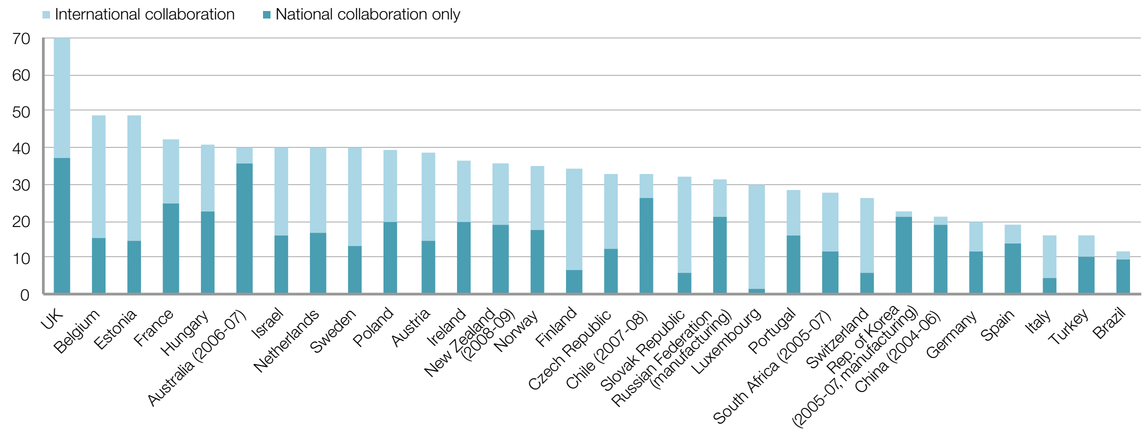
Collaboration on innovation, by R&D-intensity of firms and as a percentage of innovative firms, 2004-2006, selected countries



Note: The definitions and years underlying these data vary.[71]
Source: OECD, Working Party of National Experts in Science and Technology (NESTI) innovation microdata project based on CIS-2006, June 2009 and national data sources.

Figure 1.16: The degree and form of collaboration vary widely between countries

National and international collaboration on innovation by firms, as a percentage of innovative firms, 2006-2008, selected countries



Note: The definitions and years underlying the data vary.[72]
Source: OECD (2011), based on the Eurostat Community Innovation Survey-2008 and national data sources, June 2011.

71 For Australia, data refer to 2006-07 and innovative firms include technological and non-technological innovators; for Brazil only the following activities are included in the services sector: International Standard Industrial Classification (ISIC) Rev.4 Divisions 58, 61, 62 and 72; for Chile, data refer to 2007-08 and firms with ongoing or abandoned innovative activities are not identified. Data are based on ISIC Rev.3.1 and include a wider range of activities such as agriculture, forestry, fishing, construction, and some services; for China, data refer to 2004-06 and exclude all services. In addition, large firms are defined as firms with over 2,000 employees, over Chinese Yuan 300 million turnover and over Chinese Yuan 400 million capital. SMEs are the remaining firms with at least Yuan 5M turnover; for Korea, data refer to 2005-07 and cover only firms with more than 10 employees in the manufacturing sector. International collaboration may be underestimated; for New Zealand, data refer to 2008-09 and include firms with six or more employees. Innovative firms include technological and non-technological innovators; for the Russian Federation, data refer to manufacturing firms with 15 or more employees; for South Africa, data refer to 2005-07 and include the retail trade sector; for Switzerland, data only include R&D collaboration; for Turkey, data are based on the Classification of Economic Activities in the European Community (NACE) Rev.1.1 and exclude some activities within NACE Rev.2 Divisions J58 and J63.

72 *Idem.*

To sum up, the above and other similar statistics show that collaboration of various forms is indeed at the heart of innovation. Yet, these and other data also demonstrate that collaboration, in particular formalized forms such as R&D joint ventures or other technology alliances, are far from the norm.[73] To the contrary, there are good reasons why the extent of formal collaboration remains limited (see Chapter 3) and why other innovation strategies, for example the acquisition of other firms and their technologies, are important in practice.

Importantly, geographical proximity still matters when forming innovation-related partnerships as, despite increased internationalization, innovative activity is often conducted in clusters.

What is "open innovation" and how important is it really?

Complementing the above trend towards increased collaboration, recent contributions in the innovation literature discuss the emerging phenomenon of "open innovation".[74]

Chesbrough *et al*. (2006) defines open innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation, respectively". Increasingly, companies are said to "openly" innovate by enlarging the process to include customers, suppliers, competitors, universities and research institutes, and others, as they rely on outside ideas for new products and processes.

The business literature also refers to "crowd-sourcing", which allows firms and other organizations to find solutions to business and other challenges by seeking the expertise of a large number of potential "solvers", customers, suppliers and the like.

Table 1.2 describes four forms of open innovation, some of which involve pecuniary compensation for ideas and others that do not. Two of these forms are associated with inbound and two with outbound open innovation.

- **Inbound open innovation** is the practice of leveraging the technologies and discoveries of others. It requires the opening up to, and establishment of interorganizational relationships with, external entities. It aims to access others' technical and scientific competencies. Proprietary technologies are transferred to the initiating entity for commercial exploitation.

- **Outbound open innovation** is the practice of establishing relationships with external organizations to which proprietary technologies are transferred for commercial exploitation.

73 See Tether (2002).
74 OECD (2009); Chesbrough (2003); and Dahlander and Gann (2010).

Table 1.2 Open innovation and related practices

	Description	Opportunities	Challenges
Outbound innovation (non-pecuniary)	Internal resources are revealed to the external environment, without offering immediate financial reward, seeking indirect benefits for the focal firm. Activity: Disclose in formal & informal ways, inform and publish.	Fosters a steady stream of incremental innovation across the community of firms. Enables a marshalling of resources and a gaining of legitimacy with other innovators and firms.	Difficulty in capturing benefits that accrue. Risk of leakages.
Outbound innovation (pecuniary)	Firms commercialize their inventions and technologies by selling or licensing out resources developed in other organizations. Activity: Sell, license out, contract out.	Commercializes inventions that might otherwise have been ignored, with greater leveraging of innovative investment. Externalizes internal knowledge and inventions by communicating them to the marketplace where others might be better equipped to exploit them.	Significant transaction costs involved in transferring technologies between organizations. Difficulty in anticipating the potential and accurate value of one's own inventions.
Inbound innovation (non-pecuniary)	Firms use external sources of innovation such as competitors, suppliers, universities, etc. Activity: Learning formally and informally, crowd-sourcing, Internet solver platforms.	Allows the discoveries of others to be leveraged where complementary resources permit. Enables the discovery of new ways of solving problems.	Danger that organizations over-search by spending too much time looking for external sources of innovation and relying on them.
Inbound innovation (pecuniary)	Firms license-in and acquire expertise from outside. Activity: Buy, contract in, license in.	Ability to gain access to resources and knowledge partners. Possibility to leverage complementarities with partners.	Risk of outsourcing critical aspects of the firm's strategically important business. Effectiveness of openness hinges on resource endowments of the partnering organization. Cultural resistance within firms.

Source: WIPO adapted from Dahlander & Gann (2010) and Huizingh (2011).

All modes of collaboration shown in Table 1.2 can occur with varying degrees of openness.[75] Importantly, open innovation is almost always managed either formally, for example via contracts or firm policies, or informally, such as via community norms, trust or the implicit corporate culture.[76]

In formal settings, open innovation relies on traditional models such as licensing of various forms of IP, subcontracting, acquisitions, non-equity alliances, R&D contracts, spin-offs, joint ventures for technology commercialization, the supply of technical and scientific services, and corporate venturing investment.[77] Many of these partnership models resemble standard practices used in innovation collaboration (see Box 1.4 for examples from the biopharmaceutical industry).

75 See Gassmann and Enkel (2004).

76 See Lee *et al.* (2010).

77 See Bianchi *et al.* (2011).

Box 1.4: Open Innovation in the biopharmaceutical industry

Biopharmaceutical firms have used different organizational modes – i.e., licensing agreements, non-equity alliances, purchase and supply of technical and scientific services – to enter into relationships with different types of partners, with the aim of acquiring or commercially exploiting technologies and knowledge. These relationships can include large pharmaceutical companies, biotechnology product firms, biotechnology platform firms and universities.

A recent analysis shows at least two changes in these firms' approach to inter-organizational exchange of technologies and knowledge consistent with the open innovation paradigm: (i) biopharmaceutical firms have gradually modified their innovation network to include more and more external partners operating outside of their core areas; and (ii) alliances play an increasing role among the organizational modes implemented by these firms.

Three phases in drug development are particularly prone to the use of these innovation models:

1) **Alliances, taking place in the target identification and validation phases:** Biopharmaceutical companies establish partnerships without equity involvement in other biotech firms, pharmaceutical companies, universities or public research centers), with the aim of pursuing a common innovative objective, for example, the validation of a genetic target. Biopharmaceutical firms partner with other companies to assess certain complementary assets, for example the production capacity or distribution channels required to commercially exploit a new drug.

2) **Purchase of scientific services, related to lead identification and optimization:** Through this organizational mode, biopharmaceutical firms involve specialized players – usually biotech platform firms and, although less frequently, universities and research centers – in a specific phase of the innovation process, for example lead optimization activity, under a well-defined contractual agreement. Biopharmaceutical firms also provide technical and scientific services to third parties, which leverage the outcome of their discovery efforts.

3) **Preclinical tests and post-approval activities:** Biopharmaceutical firms acquire the rights to use a specific preclinical candidate typically from another biotech firm, a pharmaceutical company or, although less frequently, from a university.

Source: Bianchi *et al.* (2011).

Among open innovation models, new forms of inbound innovation seem particularly original. Most are Internet-enabled processes that foster customer-driven innovation such as "crowd-sourcing" and "competitions for solutions". These have taken various forms, all with the goal to generate new ideas:

- Firms or other organizations provide potential partners the possibility to submit new research projects or apply for new partnership opportunities;
- Firms solicit user feedback on new or existing products and their design;
- Firms and others host competitions and award prizes – either targeted at their own subsidiaries or suppliers, at outside professionals or the public at large.

Table 1.3 provides examples of these inbound open innovation models. While firms have already sought customer or supplier feedback in the past, the number and diversity of activity in this area is noteworthy.

Table 1.3: Open innovation platforms, selected examples

Tools or platforms to capture ideas from consumers or other contributors	• Apple's adoption of ideation software like Spigit to capture audience ideas • Portals of Starbucks, Procter & Gamble and Dell to allow customer feedback • IBM online brainstorming sessions (Jams) for employees, clients, business partners and academics
Prizes and competitions	• Tata Group Innovista competition to spur innovation among subsidiaries • Bombardier open innovation contest "You Rail", calling on designers to submit ideas for modern transportation • Peugeot Concours Design for aspiring car designers • DuPont international competition to develop surface technologies • Japanese retail chain MUJI's open innovation contests • James Dyson Award for design innovation • Seoul Cycle Design Competition 2010 for new bicycle designs • The Center for Integration of Medicine & Innovative Technology competition to improve the delivery of medical care
Co-creation platforms	• Lego Mindstorms allowing customers to create Lego designs and robots • DesignCrowd connecting clients and solvers to supply designs
Platforms connecting problems and solvers/ exchange of IP	• Various platforms for companies to post challenges: InnoCentive, Grainger, Yet2, Tynax, UTEK, NineSigma, YourEncore, Innovation Exchange, Activelinks, SparkIP • Open IDEO, a platform putting forward social challenges related to health, nutrition and education

Formal mechanisms also play a role in new Internet-based competitions and problem-solving platforms. Competitions, prizes or problem-solving platforms set up specific rules for the ideas submitted and the IP they subsequently generate (see Box 1.5). All platforms offer different IP- and other related terms of service. Yet, most if not all contain similar rules on the assignment of IP and of ownership of the ideas generated. The IP is either taken over by the initiating firm as part of the prize money, or is subject to a future licensing or other contractual arrangement.

IP and open innovation are thus often complementary. Often, the firms that file the most patent applications are – at least by their own account – the most ardent practitioners of open innovation, for example, IBM, Microsoft, Philips, Procter & Gamble.[78]

78 See Hall (2009).

Box 1.5: The attribution of ideas in open innovation contests, competitions and platforms

A review of the terms of service of InnoCentive yields the following IP-related rules:

- Individual solvers who opt to work on a specific problem featured on the platform must often sign a non-disclosure agreement before receiving the relevant information allowing them to begin searching for a solution.

- Firms already aware of a particular solver's existing IP are not obligated to pay for a solution proposing that IP. Firms should specify that "novel" solutions are required.

- Once a solver accepts the challenge award, the IP is transferred to the seeker. If the solver already holds a patent on the solution selected, the right to use that patent is transferred to the seeking entity. The solver is responsible for determining his/her ability to transfer the IP and is obligated to cooperate to ensure that the seeker obtains all rights, titles and interests in the solution and any work product related to the challenge.

- The solver must, on request, obtain a signed and notarized document from his or her employer waiving any and all rights to IP contained in the solution.

- Solutions not acquired by seekers are guaranteed not to show up in a seeker's IP portfolio at a later stage.

Source: Terms of Use, InnoCentive.[79]

Various phenomena have emerged in recent years based on Internet-enabled collaboration, sometimes without a market context, according to which individuals develop innovative solutions for the public domain. In this context, open source software, where individual software programmers invest time and resources in solving particular problems without apparent direct remuneration, has captured the most attention (see Chapter 3).

New inbound innovation models are also increasingly used for other not-for-profit objectives or to solve challenges that lie between purely commercial and non-commercial interests. Firms, universities, new entrepreneurial platforms and governments have used such contests and platforms to generate solutions to societal challenges ranging from education, access to health, access to water and other issues.

In the same spirit, collaborative efforts between the public, the non-profit and private sectors are under way which aim at inventions and innovation that the market alone might not be able to generate. New R&D funding mechanisms for solutions to rare diseases or other social challenges have attracted increasing interest.[80]

These activities have piqued the interest of scholars and practitioners alike, including in the quest to determine whether such innovative methods could be a new source of innovation.

As in the case of more traditional collaboration models, assessing the true scale and importance of open innovation is hindered by definitional and measurement challenges. Drawing a clear distinction between long-standing collaborative practices and truly new practices is difficult. Indeed, long-time existing practices, for example the identification of research partners in foreign markets, are now often relabeled by firms as part of their "open innovation" strategies.

The available data (in part discussed in the previous subsection) confirm an increased interest in leveraging external sources of knowledge to complement firms' internal activities.[81] When asked how much open innovation they are conducting, large MNEs – in particular in the IT, consumer product and, more recently, pharmaceutical sectors – claim substantial involvement in these new areas.[82] To some extent, the increased journalistic and academic attention devoted to open innovation contributes to this perceived increase. Firms are eager to portray themselves as active participants in and to show their willingness to be a part of new innovation management processes.

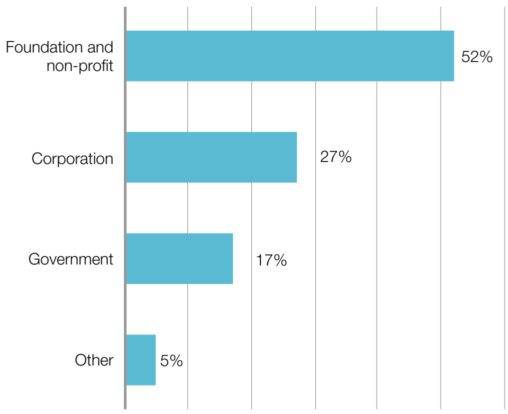
79 See *www.innocentive.com/ar/contract/view.*
80 Finally, the rise of Internet platforms is important, with attention focusing on phenomena such as user-created content on platforms such as Wikipedia and YouTube and new institutional forms such as Creative Commons, mostly relating to the production of creative works and journalism.
81 See Chesbrough and Crowther (2006).
82 See OECD (2009).

Yet, data on the actual uptake of new forms of collaborative innovation, their qualitative dimensions and effectiveness are missing. It is primarily the business management literature which has assessed the phenomenon, mostly on the basis of case studies focusing on a few sectors and firms in high-income economies. These case studies center mostly on high-technology industries, mainly the IT and to some extent the pharmaceutical sector. Follow-up studies on a more diverse set of industries, including more mature ones, are currently being undertaken to assess how fundamental this shift is across different industries.[83]

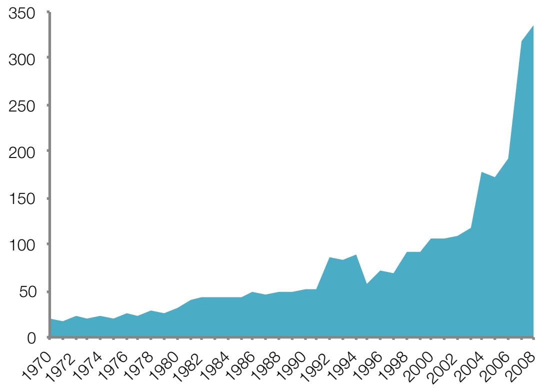
The same is true for empirical assessments of the role of prizes in the new innovation environment (see also Chapter 2 on prizes). Undeniably, their importance to innovation and policy discussions seems to be growing, albeit from a low baseline. More than 60 prizes worth at least USD 100,000 were introduced between 2000 and 2007, representing almost USD 250 million in new prize money over those seven years (see Figure 1.17).[84] The aggregate value of such large awards has more than tripled over the past decade, to USD 375 million. In comparison to total spending on business R&D in the US, however – namely USD 365 billion in 2008 alone – this figure is still exceedingly small. The source of funding for prizes has diversified (see Figure 1.17).

Figure 1.17: The sources of prizes are diversifying while the size of allocated funds is increasing from low original levels

Sources of philanthropic prizes, as a percent of total, 2000-2008



Funds allocated to prizes over USD 100,000, in USD millions, 1970-2009



Note: Based on database of 223 prizes worth USD 100,000 or more.

Source: Data obtained from Social Sector Office, McKinsey & Company, updated from McKinsey & Company (2009).

Obtaining a clear picture of the number of problems solved via competitions offering prizes or through new innovation platforms is challenging. Furthermore, assessing their contribution relative to other existing innovation channels is even harder. The related firm- or economy-wide impacts – including from the perspective of middle- or low-income countries – have not yet been seriously studied and will have to be explored further in order to demonstrate the transformative nature of these new practices.[85]

On the whole, the lack of quantitative evidence on the scope and impact of this phenomenon does mean the phenomenon should be discarded as meaningless. This holds true in particular if one accepts that most forms of innovative activity – in the present and past – have relied on some form of collaboration with varying degrees of openness.

83 See Bianchi *et al.* (2011).
84 See McKinsey & Company (2009).
85 An ongoing WIPO project on open innovation seeks to close this gap and to provide more analytical evidence. See document CDIP/6/6 on the Committee on Development and Intellectual Property's (CDIP) Open Collaborative Projects and IP-based Models at *www.wipo.int/edocs/mdocs/mdocs/en/cdip_6/cdip_6_6.pdf.*

1.3

Shifting importance of IP

IP not only drives change in the field of innovation but is itself also impacted by the changing innovation system. In the new innovation landscape, IP is a vehicle for knowledge transfer and protection, facilitating vertical disintegration of knowledge-based industries. New types of firms – and in particular new types of intermediaries – thrive as a result of their intangible IP assets. Invariably, the nature of innovation also impacts the demands on the IP system.

1.3.1

Demand and the changing geography of the IP system

A few years ago, patenting and other forms of IP activity were mostly seen as belonging to the domain of corporate legal departments, with patents used mainly in-house.

Today, an increasing number of companies treat IP as a central business asset that is managed strategically and valued and leveraged with a view to generating returns through active licensing.[86] Patents in particular are increasingly used as collateral for bank loans by patent holders, and as investment assets by financial institutions.[87] Small enterprises, newly-established or research-oriented firms depend on IP to generate revenue and use IP to obtain financing, including venture capital investments (see Chapter 2).[88] Beyond patents, business models and firm strategies tend to rely on complementary protection of trademarks, designs and copyright, although this trend and the complementarity to patent use are harder to quantify.

At the same time, there has been a shift in the IP landscape with new countries emerging as important players and greater emphasis placed on international protection of inventions. This has also invariably led to a growing demand for IP.

Growing demand for IP rights

Over the last two decades, the use of the IP system has intensified to unprecedented levels.

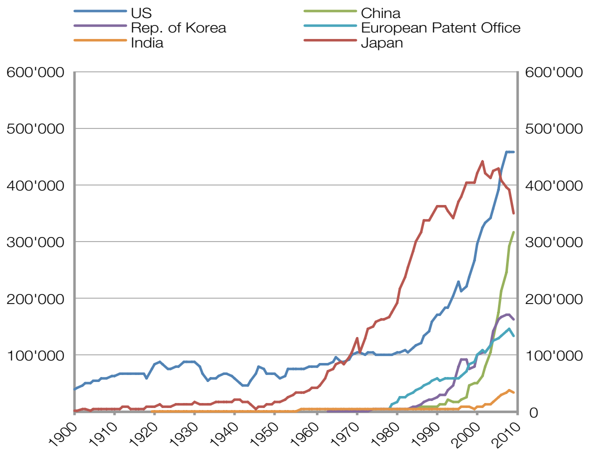
Demand for patents increased across the world from around 800,000 patent applications in the early 1980s to 1.8 million by 2009, with the greatest increase in demand occurring as of the mid-1990s. Growth in patent applications was stable until the 1970s, followed by acceleration, first in Japan and then in the US. Growth in fast-growing middle-income countries such as China and India picked up from the mid-1990s onwards (see Figure 1.18, at top).

86 See Arora *et al.* (2001); Gambardella *et al.* (2007); and Lichtenthaler (2009).
87 See Kamiyama (2005) and Otsuyama (2003).
88 See WIPO (2011d).

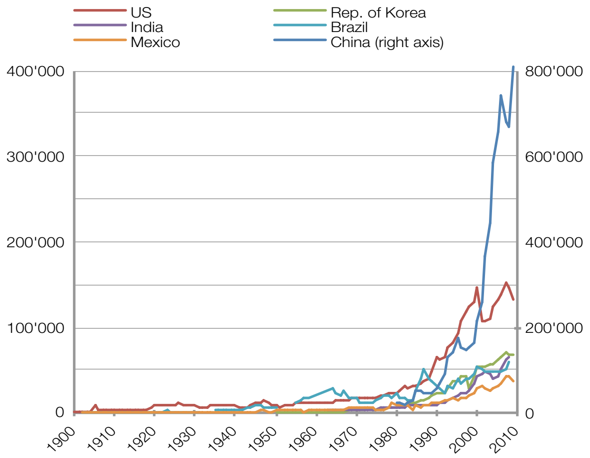
Trademark applications show a similar trend. However, accelerated activity began in the mid-1980s at the United States Patent and Trademark Office (USPTO), with trademark activity at other IP offices following during the 1990s (see Figure 1.18, at bottom). Trademark demand increased from just below one million registrations per year in the mid-1980s to 3.2 million trademark registrations by 2009.

Figure 1.18: Demand for patents and trademarks has intensified to unprecedented levels

Patent applications at selected offices, 1900-2010



Trademark applications at selected offices, 1900-2010



Note: The figures show applications data for the six top offices. Data for other large offices exhibit a similar trend. One or more classes may be specified on each trademark application, depending on whether an IP office has a single or multiclass filing system, thus complicating the comparison between countries.[89]

Source: WIPO Statistics Database, October 2011.

Other kinds of IP, such as utility models and industrial designs, have seen similar albeit smaller growth over the past decade.[90] Whereas growth in patent and trademark activity is more broad-based, increases in utility model and industrial design applications at the global level are mainly driven by China. Nonetheless, utility models have experienced substantial growth in selected countries, particularly in middle- and lower-income economies.[91] This also applies to design applications, including their international registration via the Hague System (see Box 1.6).

89 In the international trademark system and in certain IP offices, an applicant can file a trademark application specifying one or more of the 45 goods and services classes defined by the International Classification of Goods and Services under the Nice Agreement. IP offices have either a single-class or multiclass application filing system. For better international comparison of trademark application activity across offices, the multiclass system used by many national offices must be taken into consideration. For example, the offices of Japan, the Republic of Korea, the US as well as many European offices all use multiclass filing systems. The offices of Brazil, China and Mexico follow a single-class filing system, requiring a separate application for each class in which applicants seek trademark protection. This can result in much higher numbers of applications at these offices than at those that allow multiclass applications. For instance, the number of applications received by the trademark office of China is over 8.2 times that received by Germany's IP office. However, class count-based trademark application data reduce this gap to about 2.8 times. See WIPO (2010).

90 The number of worldwide utility model applications increased from around 160,000 in 2000 to approximately 310,000 in 2008, and the number of worldwide industrial design applications grew from around 225,000 in the mid-1980s to around 655,000 by 2008. The growth in utility model and industrial design applications is mostly due to the substantial increase in the level of activity in China.

91 See WIPO (2010).

Box 1.6: Design is important for product innovation

Design seems to be increasingly important in helping turn technological inventions into innovative new commercial products, i.e., facilitating the journey of technology or an invention from development through to the marketplace.[92] The latest estimates for the UK put spending on new engineering and architectural design at Great Britain Pounds (GBP) 44 billion, or 30 percent of all intangible investments.[93] This represents one and a half times the estimated expenditure by firms on training and five times the spending on R&D. A new study for the UK also shows that the majority of IP investment is on assets protected by copyright and design rights.[94]

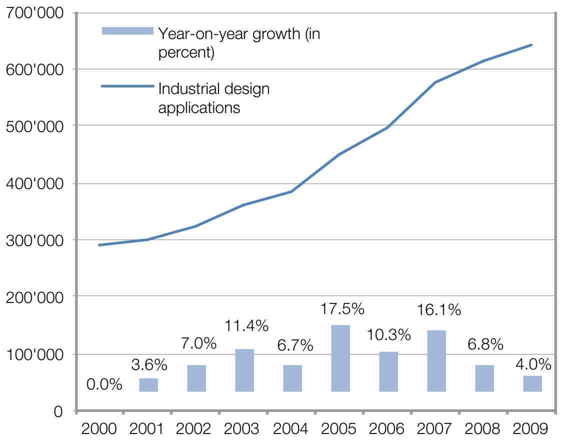
Industrial design rights can be applied to a wide variety of industrial and handicraft products, emphasizing the importance of design in innovation. The most popular industrial design classes are packages for the transport of goods and food products; clocks and watches; furniture, housewares and electrical appliances; vehicles and architectural structures; fashion and textile designs; and leisure goods. New classes for graphic logos are also increasingly filed in design registrations.

The number of industrial design applications filed worldwide in 2009 stood at approximately 640,000 (see Figure 1.19). This is the sixteenth consecutive year of growth, following a decade of stagnation. This rise in global applications can primarily be attributed to the exponential increase in industrial design applications in China. WIPO recorded 2,216 international registrations (+31.8 percent) via the Hague System in 2010, for a total of 11,238 designs (+26.7 percent).[95]

Despite these parallel increases in the importance of product design and in applications for design rights, the interaction between the two, i.e., whether the existence of design rights fosters better design, is ill-understood. Information on the share of designs covered by design rights is also not available.

Figure 1.19: Positive trend in industrial design applications after a decade of stagnation

Number of and year-on-year growth in industrial design applications, 1985-2009



Note: The world total is a WIPO estimate covering around 120 IP offices.

Source: Forthcoming World Intellectual Property Indicators Report, WIPO (2011d).

The economic literature has largely focused on understanding the surge in patent applications, which is due to a number of factors. These include a greater reliance on intangible assets and the internationalization of innovation activity. Among the factors identified as causing this surge are the following, which partly describe the same trends:

1) Increased investment in R&D and changes in the propensity to patent: The significant growth in worldwide R&D expenditure and the shift towards more applied R&D worldwide have led to more patentable inventions.[96] Furthermore, increasing levels of R&D activity in new technology fields drove increased patenting activity.

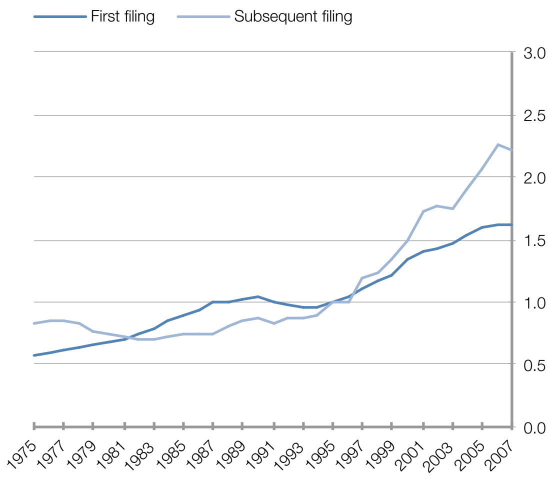
Growth in R&D expenditure and demand for patents both show an upward trend, but the growth rate of world R&D outstripped that of patent applications between 1977 and 2007. The number of patents per business R&D expenditure has thus decreased.[97] There are exceptions at the country-level, most notably in the US which has filed more patents over time per dollar spent on R&D.

92 See HM Treasury (2005).
93 See Gil and Haskell (2008).
94 See UK Intellectual Property Office (2011).
95 See WIPO (2011a).
96 See Kortum and Lerner (1999).
97 See WIPO (2011b).

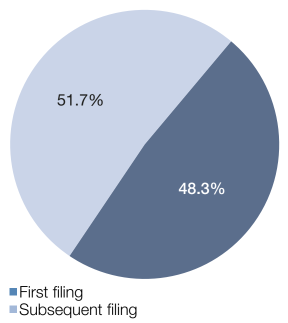
2) Growth in the number of subsequent filings: Since the mid-1990s, patenting has become increasingly internationalized. Subsequent filings reflect applicants' need to protect inventions in more than one jurisdiction. Figure 1.20 shows that subsequent filings have seen a higher growth rate compared to first filings since the mid-1990s. Patent applications grew by 83.7 percent between 1995 and 2007, and more than half of the total growth was due to subsequent filings.

Figure 1.20: Patenting in foreign jurisdictions is the main driver of growth in demand for patents

Patent applications by type of application, indexed 1995=1



Contribution of first and subsequent applications to total growth, in percent, 1995-2007



Source: WIPO (2011b).

3) Expanded technological opportunities: Computer and telecommunications technologies are some of the most important technological fields contributing to patenting growth.[98] Others are pharmaceuticals, medical technology, electrical machinery and, to a significantly lesser extent, bio- and nanotechnologies. Between 2000 and 2007, patent applications by field of technology generating the most growth were related to micro-structural and nanotechnology; digital communication and other ICT products; food chemistry; and medical technology.[99]

4) Legal and institutional changes: There have been a number of national and international legal and institutional changes to the patent system which, according to studies, have contributed to an increase in patenting activity; for example national patent reforms or the implementation of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).[100] Moreover, the PCT and Madrid systems and the European Patent Convention have facilitated cross-border patent applications.

5) Strategic patenting: Several researchers have attributed growth in patenting to so-called strategic patenting behaviors. These are practices aimed at blocking other firms from patenting, creating a thicket of defensive patents around a valuable invention to prevent competitive encroachment and litigation, and to enhance patent portfolios for cross-licensing negotiations (see Chapter 2). Some firms also use patents to block fellow competitors or to extract rents from other firms; non-practicing entities in particular have emerged which are said to litigate against other firms based on their patent portfolios.

The causes of growth in trademarks, utility models, industrial designs or other forms of IP remain relatively unexplored. In the case of copyright, it is difficult to document any baseline time trends due to the lack of data.

98 See WIPO (2011b). The growth in applications for new technologies has contributed to the surge in applications in the US.
99 See WIPO (2010).
100 See Hu and Jefferson (2009); and Rafiquzzaman and Whewell (1998).

As indicated above, more anecdotal evidence and documented use of the other forms of IP point to the fact that firms increasingly use bundles of IP rights to appropriate and market the products of their innovation. Popular products in areas such as technology, textiles, food and consumer products rely on the protection of technology, designs, trademarks and brands and often also on copyright, either for software or brand-related creative input. Again, the way the use of different forms of IP is incorporated within firms' strategies and how this determines filing behavior remain unexplored.

The demand for IP is expanding geographically

The growing demand for IP rights is also underscored by the increasing number of countries seeking IP protection.

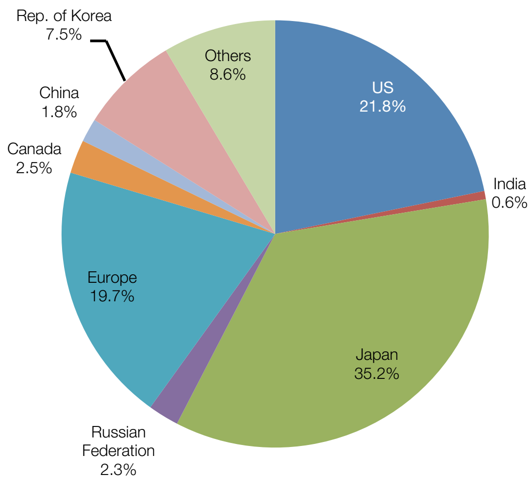
While the demand for IP rights has come mainly from Europe, Japan and the US, over the past two decades there has been a shift to other economies, most notably Asia and in particular China and the Republic of Korea. As a result, the share of global patent applications from Europe, Japan and the US dropped from 77 percent in 1995 to 59 percent in 2009. At the same time, China's share rose by more than 15 percentage points (see Figure 1.21).

PCT international application data show a similar trend. For the first time in 2010, Asia was the largest regional bloc in terms of number of PCT applications, with the strongest showing by Japan, China and the Republic of Korea (see Figure 1.22).[101]

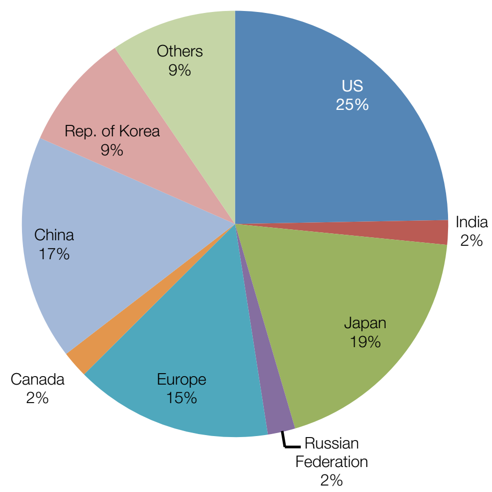
Trademark demand has always been less geographically concentrated. Europe, Japan and the US make up for around one-fifth of global trademark applications, in comparison to three-fifths for patents. However, the change in origin of trademark applications has followed a similar trend to that of patents, with China doubling its share while Europe and Japan see falling shares (see Figure 1.23).

Figure 1.21: Patent applications shift towards Asian countries

Share of IP offices in world patent applications, in percent, 1995



Share of IP offices in world patent applications, in percent, 2009

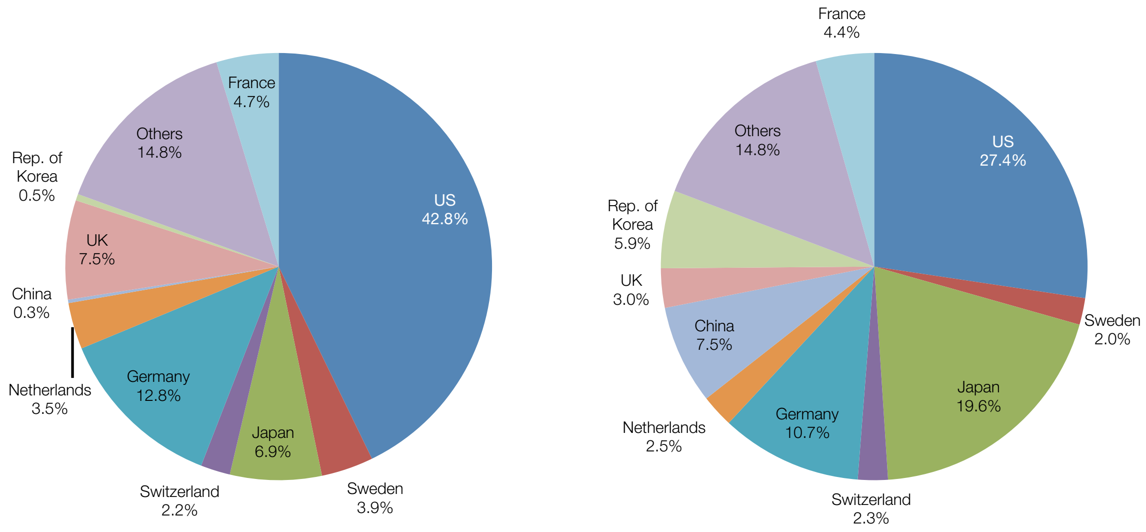


Source: WIPO Statistics Database, September 2011.

101 See WIPO (2011b).

Figure 1.22: Japan, China and the Republic of Korea become major PCT filers

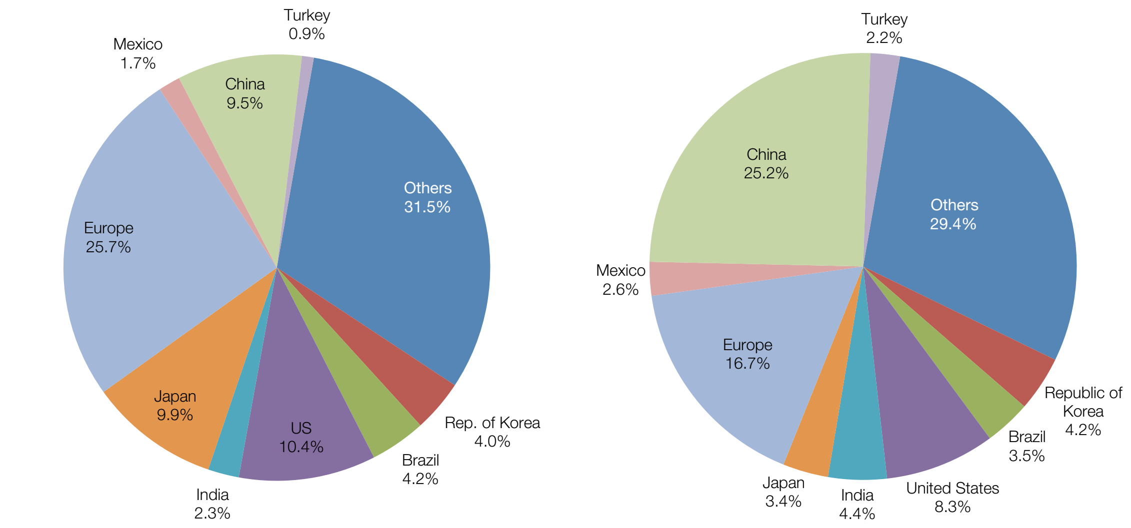
Shares of PCT applications, in percent, 1995 | **Shares of PCT applications, in percent, 2010**



Source: WIPO Statistics Database, September 2011.

Figure 1.23: Trademark applications have followed a similar internationalization trend to that of patents

Share of trademark applications worldwide, by office, in percent, 1995 | **Share of trademark applications worldwide, by office, in percent, 2009**



Note: Depending on whether an IP office has a single or multiclass filing system, one or more classes may be specified in each trademark application, thus complicating the comparison between countries.[102]
Source: WIPO Statistics Database, September 2011.

102 See footnote 89.

Table 1.4 shows the difference in patent and trademark use among income groups. Patent activity remains skewed towards high-income countries, while trademark activity is relatively more pronounced in less developed economies. Despite the drop in shares, the high-income group continues to account for the majority of patent applications. With about 57 percent of applications, middle-income economies account for most trademark applications. Low-income countries' share of trademark applications remains small and in line with their share of world GDP. Furthermore, that share has declined over time. The role of China in driving applications of all sorts in the middle-income and BRICS group is very pronounced (see Table 1.4).

Table 1.4: Patent, trademark and GDP share by income group (percent), 1995 and 2009

	Patent Applications		Trademark Applications		GPD	
	1995	2009	1995	2009	1995	2009
High-income	89.2	72.8	57.6	38.3	67.6	56.8
Upper-middle-income	8.4	23.8	31.9	48.6	23.4	31.4
…Upper middle-income excluding China	6.6	6.7	21.9	20.9	17.6	18.0
Lower middle-income	2.3	3.3	9.1	12.3	8.4	11.0
Low-income	0.1	0.1	1.3	0.8	0.6	0.8
BRICS	6.1	22.7	19.2	38.9	16.4	25.9
…BRICS excluding China	4.3	5.5	9.2	11.3	10.6	12.5

Note: Patents: High-income countries (43), upper-middle-income countries (35), lower-middle-income countries (25) and low-income countries (12). Trademarks: High-income countries (44), upper-middle-income countries (35), lower-middle-income countries (25) and low-income countries (10).

Source: WIPO Statistics Database, October 2011.

Protection of IP in international markets

The IP system is also becoming more internationalized due to reasons other than the rise in new countries making significant use of IP.

Specifically, IP rights are now also more intensively used by inventors and firms to protect their technologies, products, brands and processes abroad. Increasingly patents for one and the same invention are filed in multiple jurisdictions. In fact, such patent applications for one and the same invention filed in several countries accounted for more than half of all growth in patent applications worldwide between 1995 and 2007.[103]

Figures 1.24 and 1.25 provide evidence of increasing levels of internationalization for both patents and trademarks. Patent applications filed abroad, including PCT applications, show an upward trend. A similar pattern is observed for trademark applications filed abroad and Madrid System registrations.[104] Non-resident patent applications account for around 43 percent of all patent applications, compared to around 30 percent for trademarks.[105]

For most countries, the ratio of filings abroad compared to total resident applications has increased over time for both patents and trademarks.[106] Nonetheless, the degree of internationalization varies across countries and among IP rights. Patent filings from European countries show a high level of internationalization (see Figure 1.24, right). Among BRICS (Brazil, the Russian Federation, India, China and South Africa) countries, only India stands out as having a level of internationalization comparable to that seen in high-income economies. In relative terms, patent applications filed by residents in China or the Russian Federation are still rarely filed in other countries.[107] The situation is similar for trademarks (see Figure 1.25, right).

103 See WIPO (2011c).

104 The PCT facilitates the acquisition of patent rights in a large number of jurisdictions. Filing a trademark application through the Madrid System makes it possible for an applicant to apply for a trademark in a large number of countries by filing a single application.

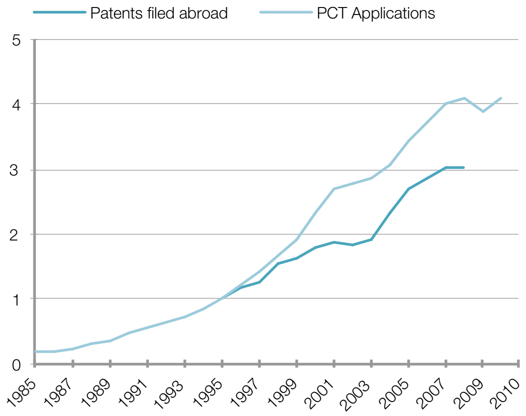
105 See WIPO (2010).

106 However, there are a few exceptions, namely Turkey for patents, and Germany, Sweden and the UK for trademarks.

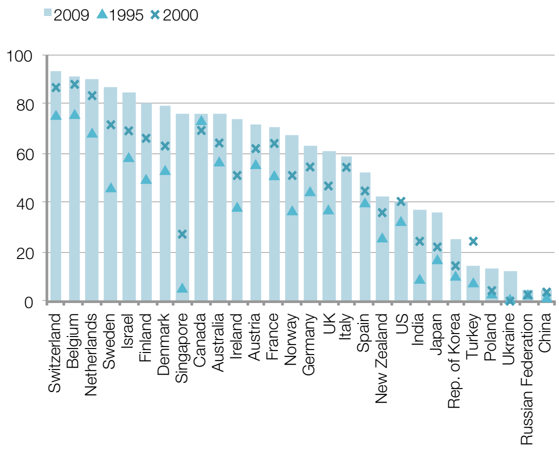
107 In absolute terms, the number of patent applications originating in China is non-trivial.

Figure 1.24: Internationalization of patent applications

Growth of patent applications abroad and PCT applications, 1995=1, 1985-2010



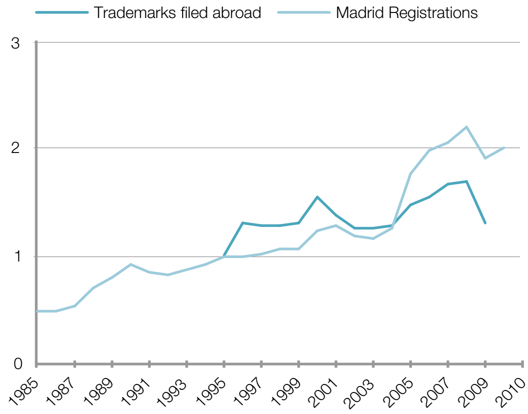
Filings abroad as a percentage of resident patent applications, selected countries, 1995, 2000 and 2009



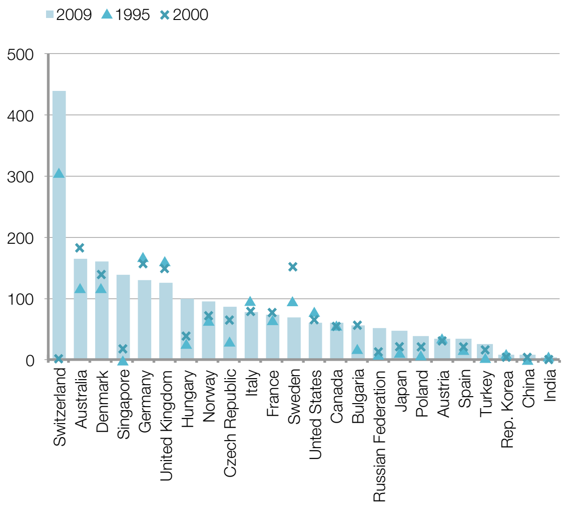
Source: WIPO Statistics Database, September 2011.

Figure 1.25: Internationalization of trademark applications

Growth of trademark applications abroad and Madrid registrations,1995=1, 1985-2010



Filings abroad as a percentage of resident trademark applications, selected countries, 1995, 2000 and 2009



Source: WIPO Statistics Database, September 2011.

Protection of utility models and industrial designs is mostly sought for the domestic market. Compared to patents and trademarks, the non-resident share out of total applications in both these forms of IP is low and declining over time – around 3 percent for utility models and 16 percent for industrial designs in the latest available year.

As technological capabilities are now more widely diffused and production more globalized, concerns relating to inadequate enforcement of IP rights, in particular patents and trademarks, have increased.

1.3.2

Increased tradability of IP

The last decades have seen an increase in licensing and other IP-based collaborative mechanisms such as patent pools. New intermediaries and IP marketplaces have also emerged.[108]

Following Arora *et al*. (2001), the literature increasingly refers to the rise in "technology markets", "knowledge markets" or "secondary markets for IP" to describe this trend. These IP-based markets are said to allow for trade in ideas and to facilitate vertical disintegration of knowledge-based industries (see Subsection 1.2.1). Firms are putting better systems in place to capture and analyze ideas both from within and without. This also enables them to capture value from IP not utilized internally. Moreover, a new type of firm has emerged which thrives solely on the creation and management of IP assets.

Increased international trade in knowledge

Existing data suggest that high-income countries make up for a large share of the international trade in knowledge and ideas, but that middle-income economies are catching up.

The most widely reported form of disembodied technology trade occurs through international receipts and payments for the use of intangible assets as measured by the payment of royalties and license fees (RLF).[109] The use of RLF data as an approximate measure of the international trade in knowledge is not without its problems. One key issue is how to isolate disembodied technology trade from transfer pricing issues (see Box 1.7). Nonetheless, RLF data are the most pertinent proxy for assessing the international trade in disembodied knowledge.

Box 1.7: The limitations of royalty and license fee data

Madeuf (1984) presents the limitations of using RLF data to infer the occurrence of technology transfer. One key problem is how to isolate technology revenue from transfer pricing. For some countries where detailed data are available, payments mostly consist of intra-firm payments, i.e., payments between subsidiaries and company headquarters – for example, 66 percent of all US receipts in 2009 and 73 percent of all US payments in 2009.[110] Given the intangible and fungible nature of IP assets between a company's headquarters and various subsidiaries, these data are subject to transfer pricing problems and related tax considerations that might be unrelated to international technology transfer between countries. Data on affiliate trade for Germany and several other European countries suggest, however, that intra-firm RLF payments made up for a lesser share, namely about 45 percent of all technology services trade from 2006-2008. Hence, for other countries this measurement problem might be a lesser one.

108 See Guellec *et al.* (2010); Howells *et al.* (2004); and Jarosz *et al.* (2010).

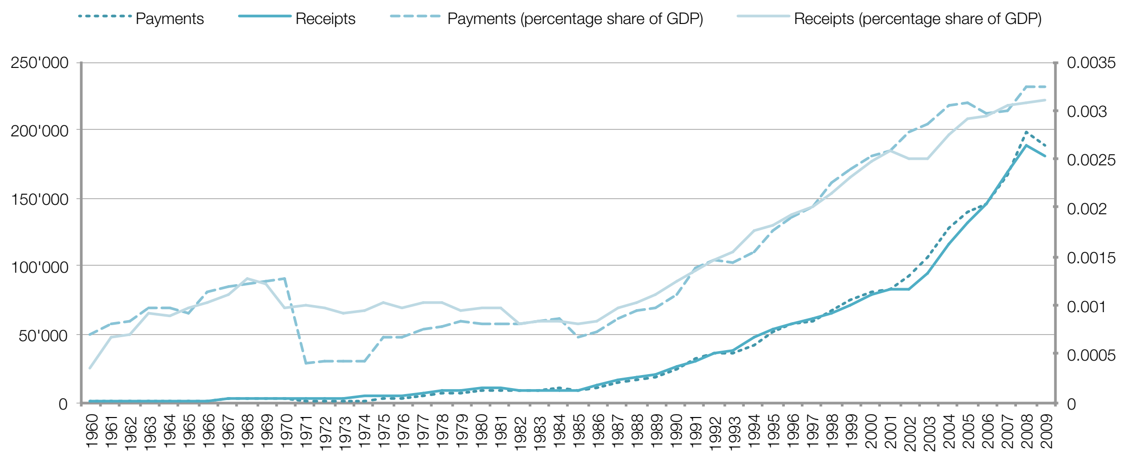
109 The International Monetary Fund (IMF) defines RLF as including "international payments and receipts for the authorized use of intangible, non-produced, non-financial assets and proprietary rights… and with the use, through licensing agreements, of produced originals or prototypes…".

110 See Koncz-Bruner and Flatness (2010); and Robbins (2009).

Figure 1.26 depicts the growth of cross-border licensing trade in the world economy and also shows the acceleration of this trade since the 1990s. In nominal terms, international RLF receipts for IP increased from USD 2.8 billion in 1970 to USD 27 billion in 1990, and to approximately USD 180 billion in 2009.[111] Over the period 1990-2009, RLF receipts and payments in the world economy grew at a fast rate – 9.9 percent per annum.[112] Even when focusing on the period since 1999, one finds a high rate of growth – about 8.8 percent per annum in nominal terms and about 7.7 percent per annum in real terms.[113] For countries where detailed data are available, it is important to note that these payments mostly consist of intra-firm payments (see Box 1.7). Although many types of activities can earn royalties, in the US, the only country with available data, industrial processes and computer software account for over 70 percent of all royalty receipts and payments.

Figure 1.26: International royalty and licensing payments and receipts are growing in absolute and relative terms

RLF payments and receipts, in USD millions (left) and as a percentage share of GDP (right), 1960-2009



Note: GDP data are from the World Bank.

Source: WIPO based on data in Athreye and Yang (2011).

111 This section relies heavily on a background report commissioned by WIPO. See Athreye and Yang (2011).

112 Some of this rise may be attributed to under-reporting or measurement issues related to the pre-1996 period.

113 The GDP deflator provided in The World Bank's World Development Indicators was used to compute the deflated values. There are numerous problems associated with finding the appropriate deflator for licensing revenue. The most commonly used deflators, GDP and consumer price index (CPI), are thought not to contain the right price indices to take into account inflation in licensing prices. A thoughtful review of the issues involved is contained in Robbins (2009), who also proposes using a deflator based on capital rentals in each country.

In 1990, 62 countries made RLF payments and, by 2007, this number had increased to 147 countries. Similarly, in 1990 only 43 countries received RLF payments but, by 2007, this number had increased to 143 countries. From 2000-2009, the BRICS economies, Ireland, the Republic of Korea, and former Eastern European nations gained in economic importance. Between 2005 and 2009, Ireland and China increased their shares of international licensing payments by 4.9 percent and 2.1 percent, respectively, while the US and UK decreased their shares by 4.1 percent and 1.9 percent.

Still today, high-income countries make up for close to 99 percent of RLF receipts – almost unchanged from ten years earlier – and for 83 percent of royalty payments – a decline from 91 percent in 1999 (see Table 1.5). Looking at US receipts one also notes little change between 2006 and 2009 in relation to their geographical composition (see Figure 1.27). The most notable transformation in the last ten years is an increased share in global payments by middle-income economies, from 9 percent in 1999 to 17 percent in 2009. Middle-income economies saw their share of receipts grow from 1 percent in 1999 to 2 percent in 2009.

Table 1.5: Royalty and license fee receipts and payments, by income groups

Income groups	1999		2009		1999	2009		
	RLF receipts and payments, in million USD				**Share of total RLF, in percent**		**Growth, 1999 to 2009, in percent**	
	Nominal	Deflated	Nominal	Deflated			Nominal	Deflated
High-income economies								
RLF receipt values	70,587	71,959	176,716	151,119	99	98	9.6	7.7
RLF payment values	67,965	70,371	155,881	135,163	91	83	8.7	6.7
Middle-income economies								
RLF receipt values	759.883	736.771	3,765	2,055	1	2	17.4	10.8
RLF payment values	6,705	6,931	3,2428	17,942	9	17	17.1	10
Low-income economies								
RLF receipt values	16	14	34	16	0.02	0.02	7.7	1.
RLF payment values	84	72	67	34	0.1	0.04	-2.3	-7

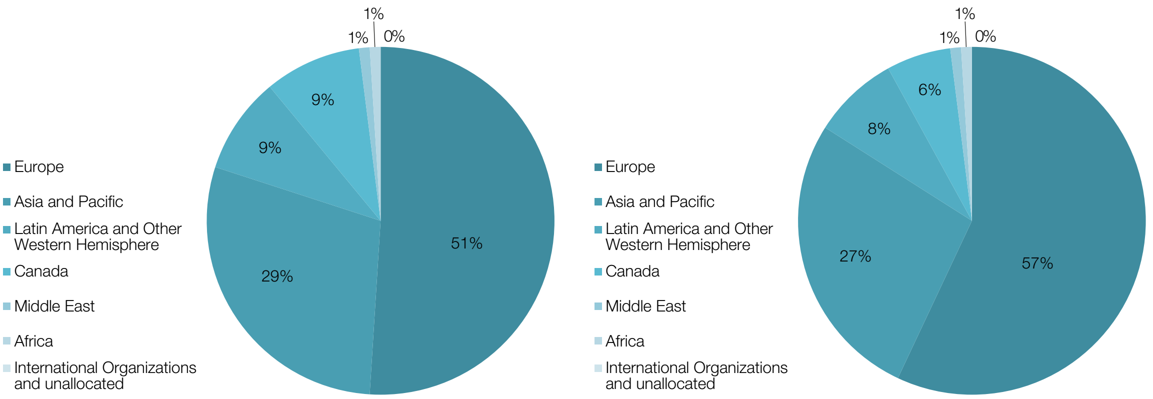
Note: The GDP deflator provided in The World Bank's World Development Indicators is used to compute the deflated values.

Source: WIPO based on data in Athreye & Yang (2011).

Figure 1.27: The geographical composition of US RLF receipts remains relatively unchanged

US royalty and license fee receipts, by emitting country as a percentage of total receipts, 2006

US royalty and license fee receipts, by emitting country as a percentage of total receipts, 2009



Note: Regions as defined by the US Bureau of Economic Analysis.

Source: WIPO, based on data from the US Bureau of Economic Analysis.

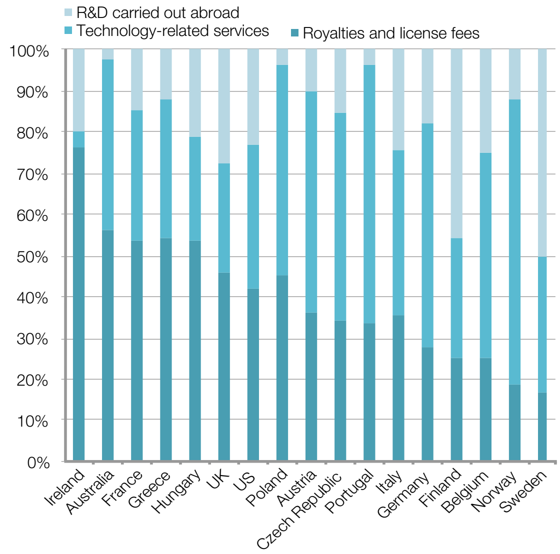
Manufacturing accounted for a large percentage of RLF payments in the six high-income countries with available data. The manufacturing sectors that dominate technology trade vary from country to country, although technology trade in chemical products, computer and office machinery and nonelectrical machinery appears to be fairly globalized.

Based on data available for high-income countries only, one can distinguish between the outright sale and purchase of patents; RLF receipts and payments for the use of intangible assets; trade in technology-related services; and receipts and payments for conducting R&D services. In the case of technology and R&D service exports, the IP rights to technology purchased usually reside with the client or buyer. This is more efficient in situations where technology transfer is likely to encounter a large tacit component requiring frequent communication or monitoring.[114]

The preferred form of disembodied technology trade differs across countries. Receipts in the UK, France and the US are mainly linked to RLFs. Ireland, Australia, France and Greece make the majority of their payments for RLF (see Figure 1.28). For other EU countries – Germany, Portugal, Norway and others – payments for technology-related services dominate. Outsourcing of R&D, captured by technology payments made for R&D services rendered abroad, accounts for only a small fraction of payments, except for Sweden and Finland, followed by Belgium, the UK and the US.

Figure 1.28: The preferred form of disembodied technology trade differs across countries

RLF payments in various high-income countries, as a percentage of the total, 2007 or last available year



Note: Purchase and sale of patents have been left out since data on theme are not consistently available. Data for France pertain to 2003; for others the reference year is 2007.

Source: WIPO based on data in Athreye and Yang (2011).

IP licensing growing from a low baseline

More disaggregated or non-trade-related data on licensing payments are harder to obtain, and complete statistics on licensing between firms do not exist. While a few private or academic sources provide aggregate figures on licensing income at the country-level, in particular for the US, these are unofficial and, most likely, imperfect estimates.[115]

114 See Athreye and Yang (2011).

115 The consulting firm IBISWorld estimates the 2010 US domestic IP licensing and franchising market to be worth around USD 25 billion, with 20.3 percent of that total attributed to patent and trademark licensing royalty income. Franchise leasing and licensing makes up more than 40 percent of that amount, and copyright licensing and leasing income more than 30 percent of total royalty income according to this source. US licensing revenue was estimated at USD 10 billion in 1990 and 110 billion in 1999, according to a different source (Rivette and Kline, 1999).

Data based on companies' annual reports as well as patenting and innovation surveys show that measurable IP-related transactions are growing but from mostly low initial levels. Better data are required to measure this phenomenon in a more timely and accurate fashion. It is also important to note that when firms enter into cross-licensing arrangements for patents, the resulting income is recorded only to the extent that cash is received. These ever-increasing transactions hence go unmeasured.

- **Annual company reports and tax filings:** In their annual reports, a minority of publicly-traded companies provide royalty revenue data (see Table 1.6 for examples). Only a few companies in the sample saw an increase in royalty revenue between 2005 and 2010. For most firms in the table, the share of RLF receipts remains between less than one to three percent of total revenue. Some firms also report other forms of IP and custom development income from technology partners. If these are taken into account, total revenue for IBM, for instance, rises to more than USD 1.1 billion in 2010, making RLF revenue 11 percent of total revenues.

Table 1.6: Shares and rates of nominal growth, selected companies, 2005 and 2010

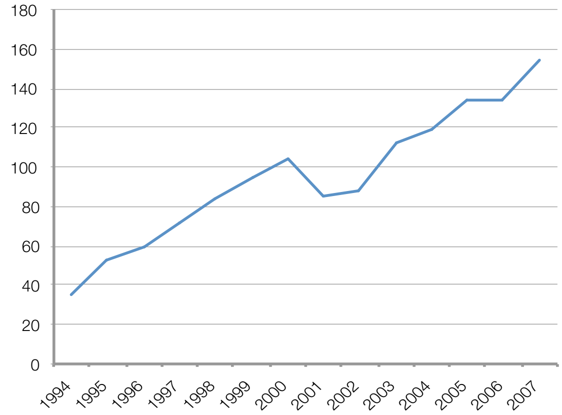
			Royalty revenue, USD millions		Royalty revenue, share of total revenue	
Company	Country	Sector	2005	2010	2005	2010
Qualcomm	US	Technology hardware & equipment	1370	4010	24.14%	36%
Philips	Netherlands	Leisure goods	665	651	1.76 %	1.86%
Ericsson	Sweden	Technology hardware & equipment	NA	638	NA	2.26%
DuPont	US	Chemicals	877	629	3.29%	1.99%
Astra Zeneca	UK	Pharmaceuticals & biotechnology	165	522	0.68%	1.61%
Merck	US	Pharmaceuticals & biotechnology	113	347	0.51%	0.75%
IBM	US	Software & computer services	367	312	0.40%	0.31%
Dow Chemical	US	Chemicals	195	191	0.42%	0.35%
Biogen Idec	US	Pharmaceuticals & biotechnology	93	137	3.84%	2.90%

Source: WIPO, based on filings at the US Security and Exchange Commission. See Gu and Lev (2004) for a more detailed but more dated analysis.

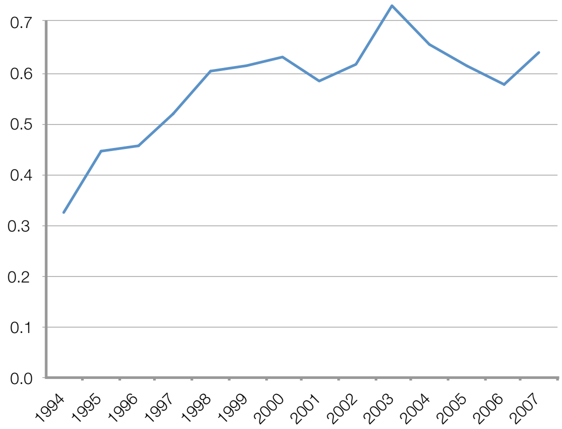
Since 1994, in the US – for which data is reported – RLF revenues have increased in nominal terms from USD 35 billion to USD 153 billion in 2007 (see Figure 1.29). The share in total company revenue remains small at 0.6 percentage points of total private sector revenue in the US. This small share can be explained by the fact that only a few US firms generate the bulk of licensing revenue. Importantly, this share has doubled since 1994.

Figure 1.29: The share of RLF receipts in company revenue remains small despite a strong increase in revenue generated by US firms

Royalties and licensing revenue, US corporations, in USD billions, 1994-2007



Royalty and licensing revenue, in percent of US corporate revenue, 1994-2007



Source: WIPO, based on data from the Internal Revenue Services (IRS) supplied by the US National Science Foundation.

- **Innovation and patenting surveys:** In Europe, around one patenting firm in five licenses patents to non-affiliated companies, whereas more than one in four does so in Japan.[116] Cross-licensing is the second most frequent motive for licensing out, both in Europe and in Japan. According to the RIETI Georgia-Tech inventor survey – conducted with US and Japanese inventors on patents with priority claims between 1995 and 2003 – licensing of patented inventions in Japan was carried out by 21 percent of firms and by 14 percent in the US.[117]

Obtaining licensing data at the sector level is challenging. Via a survey instrument, Giuri and Torrisi (2011) identify knowledge-intensive business services as the most active in licensing their technologies (see Table 1.7), followed by pharmaceuticals and electrical and electronic equipment. The majority of licensing contracts in the sample related to ICTs (in particular semiconductors/electronics), chemicals/pharmaceuticals/biotech and engineering technological classes. Intra-industry licensing comprises a large share of total recorded licensing transactions. In other words, the largest flows of technology through licensing occur within the same technological sectors.

Table 1.7: Technology flows within and between sectors, as a percentage of total technology flows

	Pharmaceuticals	Chemicals	Computers	Electrical/electronic equipment	Transport	Instruments	KIBS
Pharmaceuticals	**64.8**	3.7	0.4	0.2	0.1	4.6	11.7
Chemicals	16.9	**42.8**	1.9	3.3	2.5	4.4	9.4
Computers	0.2	1.6	**27.1**	22.4	3.1	5.6	27.7
Electrical equipment	0.8	2.1	17	**46.4**	1	4.9	20.5
Transport	2	6.7	7.84	12.8	**27.5**	5.9	24.5
Instruments	19	2.8	6.4	10.6	1.7	**29.9**	14
KIBS	10.6	2.4	9.8	10.4	1.2	2.7	**45.6**

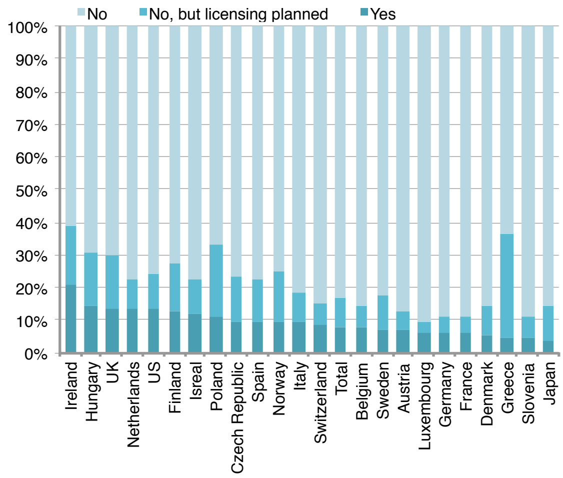
Note: KIBS stands for Knowledge-intensive business services.

Source: Gambardella *et al*. (2007).

Despite the general growth in licensing activity, only a limited share of patents is licensed out. In most countries less than ten percent of patents are subject to licensing outside the company (see Figure 1.30).[118] About 24 percent of firms in Europe declare having patents that they would be willing to license but could not. In Japan, this figure reaches 53 percent. Nonetheless, the number of firms licensing out has steadily increased over time in most countries.

Figure 1.30: The potential to license out patents is far from exhausted

Companies that license out their patents, as a percentage of total patents owned, selected high-income countries, 2003-2005



Note: Based on preliminary findings.

Source: Giuri and Torrisi (2011).

- **Universities:** Licensing out of patents by universities to firms is becoming more frequent, although the volume remains small on average and payments are mostly limited to high-income economies (see Chapter 4).

116 See Guellec and Zuñiga (2009).

117 See Michel and Bettels (2001).

118 See the PATVAL-European Union Survey.

1.3.3

New collaborative mechanisms and IP intermediaries

In Subsection 1.2.5, traditional forms of IP transactions were identified as tools for open innovation.

Technology market intermediaries have existed for a long time.[119] Already in the 1800s and early 1900s, patent agents and lawyers played an important role in matching capital-seeking inventors with investors, and in linking sellers of inventions with potential buyers.[120] Yet, beyond more traditional forms, new "collaborative mechanisms" are emerging, such as IP clearinghouses, exchanges, auctions and brokerages; model agreements; and frameworks for IP sharing.

Intermediaries are more numerous today and are equipped with novel technologies. They provide services ranging from IP management support, IP trading mechanisms, IP portfolio building to licensing, defensive patent aggregation and others. Table 1.8 describes the various actors involved and their functions.

Nonetheless, limited analysis is available on the size and scope of the actual transactions taking place. Some existing evaluations show that for some newer marketplaces, activity linked to patent auctions is only just beginning, starting from low initial levels.[121] Again, more analysis is required to determine the magnitudes and impacts of these trends.

Table 1.8: New IP intermediaries, their functions and business models

	Business models	Examples of IP intermediaries
IP management support	• IP strategy advice • Patent evaluation • Portfolio analysis • Licensing strategy advice • Patent infringement analysis, etc.	ipCapital Group; Consor; Perception partners; First Principals Inc.; Anaqua; IP strategy group; IP investments group; IPVALUE; IP Bewertungs; Analytic Capital; Blueprint Ventures; Inflexion Point; PCT Capital; Pluritas; 1790 Analytics; Intellectual Assets; IP Checkups; TAEUS; The IP exchange house; Chipworks; ThinkFire; Patent Solutions; Lambert & Lambert
IP trading mechanism	• Patent license/transfer brokerage	Fairfield Resources; Fluid Innovation General Patent; ipCapital Group; IPVALUE; TPL; Iceberg; Inflexion Point; IPotential; Ocean Tomo; PCT Capital; Pluritas; Semi. Insights; ThinkFire; Tynax; Patent Solutions; Global Technology Transfer Group; Lambert & Lambert; TAEUS
	• Online IP marketplace	InnoCentive; NineSigma; Novience; Open-IP.org; Tynax; Yet2.com; UTEK; YourEncore; Activelinks; TAEUS; Techquisition LLC; Flintbox; First Principals Inc.; MVS Solutions; Patents.com; SparkIP; Concepts community; Mayo Clinic technology; Idea trade network; Innovation Exchange
	• IP live auction/Online IP auction • IP license-right trading market	Ocean Tomo (Live auction, Patent Bid/Ask); FreePatentAuction.com; IPAuctions.com; TIPA; Intellectual Property Exchange International
	• University technology transfer	Flintbox; Stanford Office of Technology Licensing; MIT Technology Licensing Office; Caltech Office of Technology Transfer
IP portfolio building and licensing	• Patent pool administration	MPEG LA; Via Licensing Corporation; SISVEL; the Open Patent Alliance; 3G Licensing; ULDAGE
	• IP/Technology development and licensing	Qualcomm; Rambus; InterDigital; MOSAID; AmberWave; Tessera; Walker Digital; InterTrust; Wi-LAN; ARM; Intellectual Ventures; Acacia Research; NTP; Patriot Scientific RAKL TLC; TPL Group
	• IP aggregation and licensing	Intellectual Ventures; Acacia Technologies; Fergason Patent Prop.; Lemelson Foundation; Rembrandt IP Mgmt.
Defensive patent aggregation/ Framework for patent sharing	• Defensive patent aggregation funds and alliances • Initiative for free sharing of pledged patents	Open Invention Network; Allied Security Trust; RPX; Eco-Patent Commons Project; Patent Commons Project for open source software, Intellectual Discovery
IP-based financing	• IP-backed lending • Innovation investment fund • IP-structured finance • Investment in IP-intensive companies, etc.	IPEG Consultancy BV; Innovation Network Corporation of Japan; Intellectual Ventures; Royalty Pharma; DRI Capital; Cowen Healthcare Royalty Partners; Paul Capital Partners; alseT IP; Patent Finance Consulting; Analytic Capital; Blueprint Ventures; Inflexion Point; IgniteIP; New Venture Partners; Coller IP Capital; Altitude Capital; IP Finance; Rembrandt IP Mgmt.; NW Patent Funding; Oasis Legal Finance

Source: WIPO, adapted from Yanagisawa and Guellec (2009).

119 See Lamoreaux and Sokoloff (2002).
120 See Kamiyama (2005).
121 See Jarosz *et al.* (2010).

1.3.4

Emergence of new IP policies and practices

To conclude, beyond the increased use of knowledge markets and new IP intermediaries, firms and other organizations are also trialing new IP policies and practices.

For instance, firms increasingly say that they organize licensing activity and strategic alliances around an IP strategy that seeks to share technologies rather than to use IP solely as a defense mechanism. For a number of firms this represents a true change in business mentality and implies that new IP strategies are at work – moving away from the secrecy and inward-looking processes considered to be essential steps prior to applying for IP.

Companies, universities and governments are also innovating in the area of IP policy. A few select categories are listed here:

- **Publication without patenting:** Some firms opt to publish details on inventions that they do not plan to patent, often also called technical disclosures (see for example IBM's Technical Disclosure Bulletin or the IP.com Prior Art Database).[122] On the one hand, this lifts the veil of secrecy on potentially important technologies. On the other hand, it also serves the strategic aim to prevent other companies and individuals from seeking patents on the ideas, so-called defensive publishing.
- **Different forms of IP donations:** Companies can decide to release parts of their IP to the public, to fellow companies or innovators. Firms seem to have started this practice during the mid-1990s. More recently, firms have released business method patents to the public or donated IP to smaller companies. Still other firms provide royalty-free licenses for patents in the areas of food or health products. Reasons for this can be that the IP is not economically valuable to them, or that the invention requires further development efforts that the patenting firm is not willing to undertake. The extent to which these practices might be designed to preserve market share, establish or maintain standards or to crowd out competitors deserves further study.
- **Collaboration with universities:** When dealing with universities, companies are also increasingly inventive with regard to their IP policies, fostering cooperation on the one hand while ensuring control on the other (see Chapter 4). For instance, contracts often specify that the firm retains the right to require a royalty-free license on any university patent emerging from the research it has funded. University researchers are granted access to the company's internal IP, for example antibody libraries and research tools, and, in certain cases, are allowed to publish in addition to obtaining external funding (see Pfizer's new model for drug development, Philips' university partnerships, etc.). Researchers may receive extra payments if gains from developing the technology exceed original expectations.

122 www.redbooks.ibm.com

- **Contributions to patent pools:** In the last few years, a number of patent pools have been created to address health, environmental and other social challenges (see Chapter 3). The Pool for Open Innovation against Neglected Tropical Diseases, for instance, facilitates access to IP and technologies for researchers in this area.[123] Willing pharmaceutical companies or universities contribute relevant patents to the pool. The Medicines Patent Pool for AIDS medications, established with the support of UNITAID in 2010, was created to share IP through a patent pool designed to make treatments more widely affordable to the poor.[124] The Eco-Patent Commons allows ICT-related firms to make environmentally-related patents available to the public (see Box 2.4).[125] Participating firms must sign a non-assertion pledge which allows third parties royalty-free access to the protected technologies. While these patent pools are all fairly recent, so called-patent commons which support the development of open source software developers have existed for quite some time.[126]

These new IP practices can be read as a testament to firms' and other organizations' increased experimentation with new IP practices. Yet, often, firms may have recourse to these IP releases for reasons related to tax relief (as in the case of donations), overall company strategy and public relations efforts.[127] All in all, the mechanics and impacts of these IP practices require further study.

1.4

Conclusions and directions for future research

Innovation is a driver of economic growth and development. Importantly, innovative capability is no longer seen only in terms of the ability to develop new inventions. Recombining existing inventions and non-technological innovation also counts.

With increased internationalization, the way innovation activity is organized has changed. Lower- and middle-income economies contribute increasingly to technology production and innovation. Another transformation is the more collaborative nature of innovative processes. Firms are trialing different forms of "open innovation" models to leverage external sources of knowledge. That said, Chapter 1 shows that drawing a clear distinction between long-standing collaborative practices and new models – and their respective impacts – remains difficult.

In this changing context, IP both drives the changing nature of innovation and is – at the same time – impacted by these changes. Increasingly IP is treated as a central asset which is managed strategically and leveraged to generate returns. In parallel, there has been a shift in the IP landscape, with new countries emerging and greater emphasis placed on the international protection of inventions – all leading to a growing demand for the different IP forms, although patent activity remains skewed towards high-income countries, while trademark activity is relatively more pronounced in less developed economies.

123 *http://ntdpool.org/.*
124 *www.medicinespatentpool.org/.*
125 *www.wbcsd.org/web/projects/ecopatent/Eco_patent_UpdatedJune2010.pdf.*
126 *www.patentcommons.org.*
127 See Layton and Bloch (2004); and Hall and Helmers (2011).

The last decades have also seen the emergence of IP-based knowledge markets, which place greater emphasis on licensing and other IP-based collaborative mechanisms such as patent pools and new IP intermediaries. High-income countries still make up for a large share of the international trade in knowledge, but middle-income economies are catching up. Measurable IP-related transactions are growing, but from mostly low initial levels, pointing to further growth potential. Beyond traditional forms of IP licensing, new "collaborative mechanisms" have emerged. Finally, firms and other organizations are also trialing new IP policies and practices, often aimed at sharing technologies but also sometimes with a view to blocking competitors.

Areas for future research

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

- Research leading to a better understanding of the role of intangible assets in firm performance and economic growth is warranted. In this context, the positive contribution of process and organizational innovation to productivity requires further study as currently the interactions between technological and non-technological innovation are ill-understood.

- The data for assessing the frequency, type, the quality dimension and impacts of collaboration for innovation remain too limited. In this context, assessing the true importance of open innovation is hindered by definitional and measurement issues. In particular, the contribution of new innovation platforms and monetary prizes – relative to other existing innovation channels – requires further research. Also this chapter points to new inbound innovation models, new IP policies and practices – for example donations to patent pools – and other public-private efforts for not-for-profit objectives which require closer scrutiny as to their scale and effectiveness.

- Too little is known about how innovation takes place in low- and middle-income countries, how it diffuses and what its impacts are. Concepts such as "frugal" and "local" innovation and associated impacts deserve further study.

- Whereas the demand for patents has become increasingly internationalized, only a few countries are responsible for the great majority of patent filings. Understanding the causes and impacts of this fragmented patenting activity deserves study. Similarly, the different propensities and motivations of firms to use different forms of IP remain ill-understood, in particular with regard to specific country income brackets. Aside from patents, other forms of IP and their role within the innovation process deserve further study. Finally, new metrics are needed for assessing the depth and range of knowledge markets, of new IP intermediaries but also to assess which barriers exist to their further development.

REFERENCES

Aghion, P. & Howitt, P. (1992). A Model of Growth Through Creative Destruction. *Econometrica, 60*, 323-351.

Anton, J., Greene, H. & Yao, D. (2006). Policy Implications of Weak Patent Rights. In A. B. Jaffe, J. Lerner & S. Stern (Eds.), *Innovation Policy and the Economy* (Vol. 6). National Bureau of Economic Research, Inc., 1-26.

Arora, A., Fosfuri, A. & Gambardella, A. (2001). *Markets for Technology: Economics of Innovation and Corporate Strategy.* Cambridge, MA: MIT Press.

Athreye, S. & Kapur, S. (2009). Introduction: The Internationalization of Chinese and Indian Firms – Trends, Motivations and Strategy. *Industrial and Corporate Change, 18*(2), 209-221.

Athreye S., & Yang, Y. (2011). Disembodied knowledge flows in the world economy. WIPO Economics Research Working Papers, Geneva: World Intellectual Property Organization.

Benavente, J.M. & Lauterbach, R. (2008). Technological Innovation and Employment: Complements or Substitutes? *European Journal of Development Research, 20*(2), 318-329.

Bergek, A. & Bruzelius, M. (2010). Are Patents with Multiple Inventors from Different Countries a Good Indicator of International R&D Collaboration? The Case of ABB. *Research Policy, 39*(10), 1321-1334.

Bianchi, M., Cavaliere, A., Chiaroni, D., Frattini, F. & Chiesa, V. (2011). Organisational Modes for Open Innovation in the Bio-pharmaceutical Industry: An Exploratory Analysis. *Technovation, 31*(1), 22-33.

Bogliacino, F. & Perani, G. (2009). *Innovation in Developing Countries. The Evidence from Innovation Surveys.* Paper presented at the FIRB conference on Research and Entrepreneurship in the Knowledge-based Economy. Retrieved from *http://portale.unibocconi.it/wps/allegatiCTP/Bogliacino_final.pdf*

Bresnahan, T.F. & Trajtenberg, M. (1995). General Purpose Technologies "Engines of Growth?". *National Bureau of Economic Research Working Paper Series, No. 4148.*

Chesbrough, H. (2003). *Open Innovation: The New Imperative for Creating and Profiting from Technology.* Boston, MA: Harvard Business School Press.

Cohen, W.M. & Levinthal, D.A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly, 35*(1), 128-152.

Corrado, C.A., Hulten, C.R. & Sichel, D.E. (2007). Intangible Capital and Economic Growth. *Research Technology Management.*

Crepon, B., Duguet, E. & Mairesse, J. (1998). Research, Innovation and Productivity: An Econometric Analysis at the Firm Level. *Economics of Innovation and New Technoolgy, 7*(2), 115-158.

Crespi, G. & Zuñiga, P. (2010). Innovation and Productivity: Evidence from Six Latin American Countries. *IDB Working Paper Series, No. IDB-WP-218.*

Criscuolo, C., Haskel, J.E. & Slaughter, M.J. (2010). Global Engagement and the Innovation Activities of Firms. *International Journal of Industrial Organization, 28*(2), 191-202.

Dahlander, L. & Gann, D.M. (2010). How Open is Innovation? *Research Policy, 39*(6), 699-709.

David, P. A., & Foray, D. (2002). Economic Fundamentals of the Knowledge Society. SIEPR discussion paper, 01-14.

Edler, J., Fier, H. & Grimpe, C. (2011). International Scientist Mobility and the Locus of Knowledge and Technology Transfer. *Research Policy, 40*(6), 791-805.

Edquist, C. (1997). *Systems of Innovation: Technologies, Institutions and Organizations.* London: Pinter.

European Commission. (2011). Business Sector Investment in R&D. *Innovation Union Competitiveness Report 2011.* Brussels: European Commission.

Evangelista, R. & Vezzani, A. (2010). The Economic Impact of Technological and Organizational Innovations. A Firm-level Analysis. *Research Policy, 39*(10), 1253-1263.

Fagerberg, J. (1994). Technology and International Differences in Growth Rates. *Journal of Economic Literature, 32*(3), 1147-1175.

Fagerberg, J., Mowery, D.C. & Nelson, R.R. (2006). *The Oxford Handbook of Innovation.* Oxford: Oxford University Press.

Fagerberg, J., Srholec, M. & Verspagen, B. (2009). Innovation and Economic Development. *UNU Merit Working Paper Series, No. 2009-032.*

Fagerberg, J., Scrholec, M., & Verspagen, B. (2010). Innovation and Economic Development. In B. H. Hall & N. Rosenberg (Eds.), *Handbook of the Economics of Innovation (Vol. 2).* Amsterdam: North Holland, 833-872.

Filatotchev, I., Liu, X., Lu, J. & Wright, M. (2011). Knowledge Spillovers Through Human Mobility Across National Borders: Evidence from Zhongguancun Science Park in China. *Research Policy, 40*(3), 453-462.

Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan.* London: Pinter.

Freeman, C. (1994). Innovation and Growth. In M. Dodgson & R. Rothwell (Eds.), *The Handbook of Industrial Innovation*. Cheltenham, U.K.: Elgar, 78-93.

Gambardella, A., Giuri, P. & Luzzi, A. (2007). The Market for Patents in Europe. *Research Policy, 36*(8), 1163-1183.

Gil, V. & Haskell, J. (2008). *Industry-Level Expenditure on Intangible Assets in the UK.* London: Business, Enterprise and Regulatory Reform.

Giuri, P. & Torrisi, S. (2011). *The Economic Uses of Patents.* Paper presented at the Final Conference of the InnoS&T project "Innovative S&T Indicators for Empirical Models and Policies: Combining Patent Data and Surveys".

Griffith, R., Huergo, E., Mairesse, J. & Peters, B. (2006). Innovation and Productivity Across Four European Countries. *Oxford Review of Economic Policy, 22*(4), 483-498.

Griliches, Z. (1998). *R&D and Productivity:* The Econometric Evidence. Chicago: University of Chicago Press.

Grossman, G.M. & Helpman, E. (1994). Endogenous Innovation in the Theory of Growth. *The Journal of Economic Perspectives, 8*(1), 23-44.

Gu, F. & Lev, B. (2004). The Information Content of Royalty Income. *Accounting Horizons, 18*(1), 1-12.

Guellec, D., Madies, T. & Prager, J.-C. (2010). *Les marchés de brevets dans l'économie de la connaissance.* Paris.

Guellec, D. & van Pottelsberghe de la Potterie, B. (2007). *The Economics of the European Patent System: IP Policy for Innovation and Competition.* Oxford: Oxford University Press.

Guellec, D. & Zuñiga, M.P. (2009). *Who Licenses Out Patents and Why?: Lessons from a Business Survey.* Paris: OECD.

Guinet, J., Hutschenreiter, G. & Keenan, M. (2009). Innovation Strategies for Growth: Insights from OECD Countries. In C.A.P. Braga, V. Chandra, D. Erocal and P.C. Padoan (Eds.), *Innovation and Growth: Chasing a Moving Frontier.* Paris: Organisation for Economic Co-operation and Development.

Hall, B.H. (2009). *Open Innovation and Intellectual Property Rights – The Two-edged Sword.* Japan.

Hall, B. H. (2011). Innovation and Productivity. *National Bureau of Economic Research Working Paper Series, w17178.*

Hall, B.H. & Helmers, C. (2011). Innovation and Diffusion of Clean/Green Technology: Can Patent Commons Help? *National Bureau of Economic Research Working Paper Series, w16920.*

Hall, R.E. & Jones, C.I. (1999). Why Do Some Countries Produce So Much More Output Per Worker than Others? *The Quarterly Journal of Economics, 114*(1), 83-116.

HM Treasury (2005). *The Cox Review of Creativity in Business.* London: Design Council.

Howells, J., James, A.D. & Malik, K. (2004). Sourcing External Technological Knowledge. *International Journal of Technology Management, 27*(2/3).

Hu, A.G. & Jefferson, G.H. (2009). A Great Wall of Patents: What is Behind China's Recent Patent Explosion? *Journal of Development Economics, 90*(1), 57-68.

Huizingh, E.K.R.E. (2011). Open Innovation: State of the Art and Future Perspectives. *Technovation, 31*(1), 2-9.

Hulten, C.R. & Isaksson, A. (2007). Why Development Levels Differ: The Sources of Differential Economic Growth in a Panel of High and Low Income Countries. *National Bureau of Economic Research Working Paper Series, No. 13469.*

Ivarsson, I. & Alvstam, C.G. (2010). Supplier Upgrading in the Home-furnishing Value Chain: An Empirical Study of IKEA's Sourcing in China and South East Asia. *World Development, 38*(11), 1575-1587.

Jarosz, J., Heider, R., Bazelon, C., Bieri, C., & Hess, P. (March 2010). *Patent Auctions: How Far Have We Come?* les Nouvelles, 11-30.

Jones, C.I. & Romer, P.M. (2010). The New Kaldor Facts: Ideas, Institutions, Population, and Human Capital. *American Economic Journal: Macroeconomics, 2*(1), 224-245.

Kamiyama, S. (2005). *Intellectual Property as an Economic Asset: Key Issues in Valuation and Exploitation.* Paper presented at Intellectual Property as an Economic Asset: Key Issues in Valuation and Exploitation, Berlin.

Khan, M. (2005). Estimating the Level of Investment in Knowledge Across the OECD countries. In A. Bounfour & L. Edvinsson (Eds.), *Intellectual Captial for Communities: Nations, Regions, and Cities*. London: Butterworth-Heinemann.

Khan, M., & Luintel, K. B. (2006). *Sources of Knowledge and Productivity: How Robust is the Relationship?* OECD STI Working Papers, 2006/06.

Klenow, P.J. & Rodríguez-Clare, A. (1997). Economic Growth: A Review Essay. *Journal of Monetary Economics, 40*(3), 597-617.

Koncz-Bruner, J. & Flatness, A. (2010). *U.S. International Services Cross-Border Trade in 2009 and Services Supplied Through Affiliates in 2008.* Washington, D.C.: US Bureau of Economic Analysis.

Kortum, S. & Lerner, J. (1999). What is Behind the Recent Surge in Patenting? *Research Policy, 28*(1), 1-22.

Lamoreaux, N.R. & Sokoloff, K.L. (2002). Intermediaries in the U.S. Market for Technology, 1870-1920. *National Bureau of Economic Research Working Paper Series, No. 9017.*

Layton, R. & Bloch, P. (2004). *IP Donations: A Policy Review.* Washington, D.C.: International Intellectual Property Institute.

Lee, N., Nystén-Haarala, S. & Huhtilainen, L. (2010). *Interfacing Intellectual Property Rights and Open Innovation.* Lappeenranta University of Technology, Department of Industrial Management.

Lichtenthaler, U. (2009). The Role of Corporate Technology Strategy and Patent Portfolios in Low-, Medium- and High-technology Firms. *Research Policy, 38*(3), 559-569.

Long, J.B.D. (1988). Productivity Growth, Convergence, and Welfare: Comment. *The American Economic Review, 78*(5), 1138-1154.

Lundvall, B.A. (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London: Pinter.

Mairesse, J. & Mohnen, P. (2010). Innovation Surveys for Econometric Analysis. *Handbook of the Economics of Innovation.* Amsterdam: Elsevier.

Mairesse, J. & Mohnen, P. (2010). Using Innovation Surveys for Econometric Analysis. *National Bureau of Economic Research Working Paper Series, 15857.*

McKinsey & Company. (2009). "And the Winner is…": *Capturing the Promise of Philanthropic Prizes.* McKinsey & Company.

Mendonça, S. (2009). Brave Old World: Accounting for "High-tech" Knowledge in "Low-tech" Industries. *Research Policy, 38*(3), 470-482.

Michel, J. & Bettels, B. (2001). Patent Citation Analysis – A Closer Look at the Basic Input Data from Patent Search Reports. *Scientometrics, 21*(1), 185-201.

Narula, R. (2010). *Much Ado about Nothing, or Sirens of a Brave New World? MNE Activity from Developing Countries and Its Significance for Development.* Maastricht: United Nations University, Maastricht Economic and Social Research and Training Centre on Innovation and Technology.

National Science Board (2010). *Science and Engineering Indicators 2010.* Arlington, VA: National Science Foundation.

Ocean Tomo (2010). *Ocean Tomo's Intangible Asset Market Value Study.* Chicago: Ocean Tomo.

OECD (2009). *Open Innovation in Global Networks.* Paris: Organisation for Economic Co-operation and Development.

OECD (2010a). *Innovation in Firms.* Paris: Organisation for Economic Co-operation and Development.

OECD (2010b). *Measuring Innovation – A New Perspective.* Paris: Organisation for Economic Co-operation and Development.

OECD (2010c). *The OECD Innovation Strategy: Getting a Head Start on Tomorrow.* Paris: Organisation for Economic Co-operation and Development.

OECD (2010d). *OECD Science, Technology and Industry Outlook 2010.* Paris: Organisation for Economic Co-operation and Development.

OECD (2010e). *Perspectives on Global Development 2010.* Paris: Organisation for Economic Co-operation and Development.

OECD (2011). *OECD Science, Technology and Industry Scoreboard 2011.* Paris: Organisation for Economic Co-operation and Development.

OECD & Eurostat (2005). *Oslo Manual: Guidelines for Using and Interpreting Innovation Data.* Paris: Organisation for Economic Co-operation and Development.

Otsuyama, H. (2003). Patent Valuation and Intellectual Assets Management. In M. Samejima (Ed.), *Patent Strategy Handbook.* Tokyo: Chuokeizai-sha.

Parisi, M.L., Schiantarelli, F. & Sembenelli, A. (2006). Productivity, Innovation and R&D: Micro Evidence for Italy. *European Economic Review, 50*(8), 2037-2061.

Pinkovskiy, M., & Sala-i-Martin, X. (2009). Parametric Estimations of the World Distribution of Income. *National Bureau of Economic Research Working Paper Series, 15433.*

Prahalad, C.K. & Lieberthal, K. (1998). The End of Corporate Imperialism. *Harvard Business Review, 76*(1), 69-79.

Rafiquzzaman, M., & Whewell, L. (1998). *Recent Jumps in Patenting Activities: Comparative Innovative Performance of Major Industrial Countries, Patterns and Explanations.* Industry Canada Research Working Paper, 27.

Ray, P.K. & Ray, S. (2010). Resource Constrained Innovation for Emerging Economies: The Case of the Indian Telecommunications Industry. *IEEE Transactions on Engineering Management, 57*(1), 144-156.

Rivette, K.G. & Kline, D. (1999). *Rembrandts in the Attic: Unlocking the Hidden Value of Patents.* Harvard Business Press.

Robbins, C.A. (2009). Measuring Payments for the Supply and Use of Intellectual Property. In M. Reinsdorf & M.J. Slaughter (Eds.), *International Trade in Services and Intangibles in the Era of Globalization*. Chicago: University of Chicago Press.

Romer, P. (1986). Increasing Returns and Long-Run Growth. *Journal of Political Economy, 94*(5), 1002-1037.

Romer, P. (2010). Which Parts of Globalization Matter for Catch-up Growth? *National Bureau of Economic Research Working Paper Series, 15755.*

Royal Society (March 2011). *Knowledge, Networks and Nations: Global Scientific Collaboration in the 21st Century.* London.

Schumpeter, J.A. (1943). *Capitalism, Socialism, and Democracy: Harper Perennial.*

Tether, B.S. (2002). Who Co-operates for Innovation, and Why: An Empirical Analysis. *Research Policy, 31*(6), 947-967.

Tether, B.S. & Tajar, A. (2008). The Organisational-Cooperation Mode of Innovation and Its Prominence Amongst European Service Firms. *Research Policy, 37*(4), 720-739.

UK Intellectual Property Office (2011). *The Role of IP Rights in the UK Market Sector.* London: UK Intellectual Property Office.

UNCTAD (2011). *World Investment Report 2011.* Geneva: United Nations Conference on Trade and Development.

UNESCO (2010). *UNESCO Science Report 2010.* Paris: United Nations Educational, Scientific and Cultural Organization.

UNIDO (2009). *Industrial Development Report – Breaking in and Moving Up: New Industrial Challenges for the Bottom Billion and the Middle-Income Countries.* Vienna: United Nations Industrial Development Organization.

van Ark, B. & Hulten, C.R. (2007). *Innovation, Intangibles and Economic Growth: Towards A Comprehensive Accounting of the Knowledge Economy*: The Conference Board.

WIPO (2010). *World Intellectual Property Indicators.* Geneva: World Intellectual Property Organization.

WIPO (2011a). *Hague System for the International Registration of Industrial Designs – Report for 2010.* Geneva: World Intellectual Property Organization.

WIPO (2011b). PCT – *The International Patent System – Yearly Review – Developments and Performance in 2010.* Geneva: World Intellectual Property Organization.

WIPO (2011c). The Surge in Worldwide Patent Applications, *PCT/WG/4/4*. Study prepared for the Patent Cooperation Treaty (PCT) Working Group. Geneva: World Intellectual Property Organization.

WIPO (2011d). Patenting and the Crisis, WIPO Survey on Patenting Strategies in 2009 and 2010. Geneva: World Intellectual Property Organization.

WIPO (2011e, forthcoming). *World Intellectual Property Indicators.* Geneva: World Intellectual Property Organization.

World Bank (2008). *Global Economic Prospects 2008.* Washington, D.C.: World Bank.

Wunsch-Vincent, S. (2006). China, Information Technologies and the Internet. In OECD (Ed.), *OECD Information Technology Outlook.* Paris: Organisation for Economic Co-operation and Development, 139-182.

Yanagisawa, T. & Guellec, D. (2009). The Emerging Patent Marketplace. Directorate for Science, Technology and Industry Working Paper 2009/9. Paris: Organisation for Economic Co-operation and Development.

Young, A. (1993). Lessons from the East Asian NICs: A Contrarian View. *National Bureau of Economic Research Working Paper Series, No. 4482.*

Young, A. (1995). The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. *The Quarterly Journal of Economics, 110*(3), 641-680.

Zuñiga, P. (2011). The state of patenting at research institutions in developing countries: Policy approaches and practices. WIPO Economics Research Working Papers, Geneva: World Intellectual Property Organization.

CHAPTER 2
THE ECONOMICS OF INTELLECTUAL PROPERTY – OLD INSIGHTS AND NEW EVIDENCE

Innovation holds the potential to improve human well-being and generate economic prosperity. Understanding why individuals and organizations innovate and how government policies affect innovative behavior are therefore important. Throughout history, economists have studied these questions and devised different theories to explain incentives for innovation.

This chapter focuses on the role of the intellectual property (IP) system in the innovation process and has two main objectives. It first seeks to convey, from the standpoint of economists, the key ideas behind the IP system, including the main rationales for protecting IP rights as well as their pros and cons compared to other innovation policy instruments (Section 2.1).

The second objective is to explore how economists' understanding of the IP system has changed, by taking a closer look at the patent system which has received, by far, the most scrutiny by researchers (Section 2.2). While many old insights still apply, economists have gained new empirical perspectives which have led to a more refined view of how patent protection affects innovation. These new perspectives partly reflect real world developments – as reviewed in Chapter 1 – and also better data, which enable richer investigations.

One important theme that emerges from the recent literature is the key role patent institutions play in determining innovation outcomes. Since this theme is of special relevance for IP policymaking, the chapter elaborates on some of the challenges facing these institutions (Section 2.3). The concluding remarks summarize some of the key messages emanating from the economic literature and point to areas where more research could usefully guide policymakers (Section 2.4).

2.1

Understanding IP rights and their role in the innovation process

The importance of innovation in economic thinking can be traced as far back as 1776. In his famous treatise on the Wealth of Nations, Adam Smith notes that "the invention of all those machines by which labour is so much facilitated and abridged seems to have been originally owing to the division of labour." He further observes that "[a] great part of the machines […] were originally the inventions of common workmen, who, being each of them employed in some very simple operation, naturally turned their thoughts towards finding out easier and readier methods of performing it."[1]

1 See Smith (1776).

But it was not until the second half of the 20th century that scholars started to scrutinize the circumstances of inventive activity more closely, rather than simply viewing it as a "natural turn of thought". In 1962, Nobel-prize winning economist Kenneth J. Arrow helped galvanize economic thinking in this area by arguing that the inventive process – viewed as the production of problem-solving information – faces two fundamental difficulties.[2] First, it is a risky process: when embarking on a problem-solving exercise, it is uncertain whether a solution can really be found. Second, information related to problem-solving possesses characteristics of what economists call a public good: many people can simultaneously use it, and the problem solver often cannot prevent reproduction of the information. The latter characteristic is also known as the *appropriability dilemma* of inventive activity.

In view of these two fundamental difficulties, Arrow concluded that, left alone, markets would underinvest in inventive activity relative to what would be socially desirable. To avoid wasting resources should a problem-solving effort fail, firms operating in competitive markets may forgo inventive opportunities; and, if competitors can immediately free ride on a successful solution, the inventing firm may reap little financial reward.

In view of the innovative behavior observed in markets, these conclusions may seem overly pessimistic. Much invention occurs due to innate curiosity. Some inventors thrive on inventive challenges that carry a high risk of failure. Recognition from peers or society at large for solving a complex problem is another important factor driving creativity and inventiveness. In some cases, such recognition may ultimately lead to a tangible reward in the form of future job offers or access to the venture capital market. Lerner and Tirole (2005), for example, find that reputational benefits are a key factor motivating software programmers to participate in open source software projects.

There are also mechanisms for reducing risks and appropriating inventive efforts in private markets. The pooling of inventive activity within larger firms diminishes the uncertainty of inventive outcomes, as successes make up for failures. Pooling can also be achieved through financial markets, notably through venture capital funds. In addition, firms can often overcome appropriability problems by being first to introduce a new good or service on the market; even a short lead time may be sufficient to generate enough profits to make inventive investment worthwhile. Creating consumer goodwill through extensive marketing of new products can also give firms a competitive edge, allowing them to finance inventive activity. Indeed, surveys of firms over the past decades have shown that, in many sectors, lead time and marketing are some of the most important ways of appropriating returns on inventive activity.[3]

However, problems of appropriability and risk in innovative activity persist even where private markets offer certain innovation incentives. To begin with, although individuals may invent purely out of curiosity, they also need to earn a living. Pushing the limits of the world's knowledge frontier requires talent, but often it also demands years of experience, collaboration within larger research teams and expensive equipment. In addition, successful innovation in modern economies not only requires smart inventions, but also substantial investment in the subsequent development and commercialization of new products. In many cases, market mechanisms are bound to be insufficient for inducing innovation that is in society's best interest, thus providing a rationale for government intervention.

2 See Arrow (1962). In the 1930s, Joseph Schumpeter (1937, 1943) had already recognized that firms with market power were in a better position to innovate. However, his analysis focused primarily on how firm size affects innovative behavior and entrepreneurship; he had not yet explored the special economic attributes of information goods as was later done by Arrow.

3 Subsection 2.3.1 summarizes the results of these surveys.

Against this background, this section looks at the IP system as one form of government intervention to promote innovation. It explores how the IP system shapes innovation incentives (Subsection 2.1.1), which considerations go into designing IP rights (Subsection 2.1.2) and how those rights compare to other innovation policy instruments (Subsection 2.1.3).

Before proceeding, one caveat is in order. Most economic research on IP protection has focused on patents, but many insights also apply to other forms of IP. For that reason, this section refers to "IP rights" generically. Where relevant, the discussion points to important differences between the various forms of IP. Trademark rights are, however, excluded from the discussion. While their enabling of firms to appropriate innovative efforts through marketing makes them indirectly relevant to innovation, the economics of trademark protection involves fundamentally different considerations which, for space constraints, are not discussed here.[4]

2.1.1

How IP protection shapes innovation incentives

IP protection is a policy initiative that provides incentive for undertaking creative and innovative activity. IP laws enable individuals and organizations to obtain exclusive rights to their inventive and creative output. Ownership of intellectual assets limits the extent to which competitors can free ride on problem-solving and related information, enabling owners to profit from their efforts and addressing the appropriability dilemma at its heart.

Table 2.1 describes the five forms of IP most relevant to innovation – patents and utility models, industrial designs, copyright, plant variety rights and trade secrets. These IP forms have emerged historically to accommodate different forms of innovative and creative output.

Table 2.1: Main forms of IP rights available to innovators

IP right	Subject matter	Acquisition of right	Nature of right: prevent others from…
Patents and utility models	Inventions that are new, non-obvious and industrially applicable	Granted by government authority, typically following substantive examination	… making, using, selling, offering for sale or importing
Industrial designs	Industrial designs that are new and/or original	Granted by government authority upon registration, with or without substantive examination	… making, selling or importing
Copyright	Creative expressions	Automatically, upon creation	… reproducing and related acts
Plant variety rights	Plant varieties that are new, distinct, uniform and stable	Granted by government authority following substantive examination	… using and multiplying propagating materials
Trade secrets	Any valuable confidential business information	Automatically, upon creation	… unlawfully disclosing

Note: This table offers an intuitive overview of the main forms of IP and, only incompletely, describes the legal character of these rights, as established through national laws and international treaties. For a detailed legal introduction, see Abbott *et al*. (2007). Trademarks are not included here, as explained in the text.

4 The main economic rationale for protecting trademark rights is to resolve problems of asymmetric information between buyers and sellers. There is a similar rationale behind the protection of geographical indications. See, for example, Fink *et al*. (2005).

IP rights are an elegant means for governments to mobilize market forces to guide innovative and creative activity. They allow decisions on which innovative opportunities to pursue to be taken in a decentralized way. To the extent that individuals and firms operating at the knowledge frontier are best-informed about the likely success of innovative projects, the IP system promotes an efficient allocation of resources for inventive and creative activity.

This has traditionally been the key economic rationale for protecting IP rights. However, there are a number of additional considerations, some of which strengthen the case for exclusive rights, while others weaken it.

First, while IP rights do not directly solve the problem of risk associated with inventive activity, they can improve the functioning of financial markets in mobilizing resources for risky innovation. In particular, the grant of a patent at an early stage in the innovation process can serve to reassure investors that a start-up firm is in a position to generate profits if the invention is successfully commercialized. In addition, it provides an independent certification that an invention pushes the limits of the knowledge frontier – something that investors may not be able to assess on their own.[5]

Second, inventing sometimes means finding solutions to stand-alone problems. More often, however, it is a cumulative process, whereby researchers build on existing knowledge to develop new technologies or products. The IP system plays an important role in the process of cumulative innovation.[6]

Patent applicants must disclose the problem-solving information underlying an invention in return for being granted exclusive rights. This promotes timely disclosure of new technological knowledge, and allows follow-on inventors to build on that knowledge. In some cases, problem-solving information can easily be discerned from a new product on the market – as is naturally the case for new designs and most creative expressions.[7] In other cases, however, reverse engineering may take substantial time and effort, or it may be altogether impossible. In the absence of patent rights, inventors would have every incentive to keep their inventions secret. At the extreme, valuable inventions would die with their inventors.

Even though patent laws provide for express exceptions on using patented technologies for research purposes, patents may nonetheless create a barrier for follow-on innovators. Notably, certain technology fields are characterized by complex patent landscapes, generating uncertainty about whether potential new inventive output could clash with existing proprietary rights. A related problem arises where the commercialization of an invention requires use of third-party proprietary technology. Other right holders may refuse to license their technologies or may demand royalties that render the innovation unprofitable – leading to the so-called holdup problem. Even where they are willing to license, coordinating the participation of a large number of right holders may be too costly.[8]

5 See, for example, Greenberg (2010) and Dushnitski and Klueter (2011).

6 See, for example, Scotchmer (1991).

7 Computer software is an important exception. The source code for a particular software can be technologically protected from disclosure. Copyright protection does not oblige the owner to disclose the source code.

8 See, for example, Eisenberg (1996) and Shapiro (2001).

Third, the IP system facilitates firm specialization in different stages of the innovation process. As argued in Chapter 1, the traditional view of research, development and commercialization undertaken by a single firm does not reflect innovation processes in modern economies. For example, while a given firm may find it is particularly good at figuring out how to extend the life of batteries, other companies might be better at turning the underlying inventions into components for different consumer electronics. Similarly, a firm may know how best to market a new kitchen utensil in its home market, but prefer to partner with another firm in an unfamiliar foreign market. Specialization allows firms to maximize an inherent advantage, ultimately enhancing the economy-wide productivity of the innovation process.

Economic theory holds that specialization occurs wherever the transaction cost of providing specific goods or services through the market is lower than the costs of coordination within a single organization.[9] Specialization in the innovation process relies on markets for technology. Compared to markets for standardized commodities, technology markets face especially high transaction costs – in the form of information, search, bargaining, enforcement and related costs.[10]

To some extent, IP rights can reduce these costs. In the absence of patent rights, for instance, firms would be reluctant to disclose secret but easy-to-copy technologies to other firms when negotiating licensing contracts.[11] As a result, licensing agreements from which all parties stand to benefit might never materialize. In addition, while inventive and creative assets can, in principle, be transferred through private contracts independent of any IP right, IP titles offer a delineation of these assets combined with an assurance of market exclusivity. IP rights thus convey important information that can facilitate the drawing up of contracts and reduce the uncertainty of contracting parties as to the commercial value of the licensed assets.

Fourth, the grant of exclusive IP rights affords firms market power, viewed by economists as the ability to set prices above marginal production costs. In many cases, market power emanating from an IP right is limited, as companies face competition from similar products or technologies. However, for radical innovation – say, a pharmaceutical product treating a disease for which no alternative treatment exists – market power can be substantial. The ability of companies to generate profits above competitive levels – also called economic rents – is part of the economic logic of the IP system. Economic rents allow companies to recoup their initial investment in research and development (R&D). In other words, economic rents are at the core of the solution to the appropriability problem.

However, market power also implies a non-optimal allocation of resources, moving markets away from the economic ideal of perfect competition. Above-marginal cost pricing can raise social concerns, as witnessed by the debate on patents and access to medicines. It can also slow the adoption of new technologies, with follow-on effects on economic productivity. Finally, scholars have long recognized that the existence of economic rents may promote rent-seeking behavior with wasteful or outright harmful consequences.[12]

9 See, for example, Coase (1937) and Alchian and Demsetz (1972).
10 See Arora *et al.* (2001b) and Arora and Gambardella (2010).
11 See Williamson (1981) and Arrow (1971).
12 See Tullock (1987) for a discussion of the economics of rent-seeking.

The foregoing discussion reveals that IP rights have multiple effects on innovative behavior. Understanding their net effect ultimately requires empirical insight. Generating credible empirical evidence is a difficult task, however. Unlike in the natural sciences, economists usually cannot conduct experiments, say, by randomly assigning IP rights to companies or IP laws to countries. Historical experience sometimes offers quasinatural experiments, allowing for important insights – as illustrated by research on innovation in the 19th century (see Box 2.1). However, it is not clear whether these insights still apply to today's more evolved innovation systems and economic structures.

Box 2.1: How did patent laws affect innovation in the 19th century?

In the mid-19th century, countries in northern Europe protected patents to varying degrees. A few – such as Denmark, the Netherlands and Switzerland – did not provide for patent protection during certain periods. Where protection was available, it varied from 3 to 15 years. Countries adopted patent laws in a relatively ad hoc manner, influenced more by legal traditions than economic considerations.

Economic historian Petra Moser (2005) analyzed whether this variation in national patent laws influenced innovation outcomes. In particular, she collected data on close to 15,000 inventions presented at the Crystal Palace World's Fair in 1851 and the Centennial Exhibition in 1876; her dataset covered inventions from 13 northern European countries across 7 industries. She then asked whether patterns of innovation in countries that provided for patent protection differed from those that did not.

Her findings suggest that innovators in countries without patent laws focused on a small set of industries where innovation could be appropriated through secrecy or other means – most notably, scientific instruments. By contrast, innovation in countries with patent laws appeared to be more diversified. These findings suggest that innovation takes place even in the absence of patent protection; however, the existence of patent laws affects the direction of technical change and thus determines countries' industrial specialization.

Notwithstanding these difficulties, economic research has generated useful empirical evidence for evaluating the impact of IP rights on innovation. Section 2.2 – as well as Chapters 3 and 4 – will further review this evidence. However, before doing so, it is instructive to explore the implications of the above considerations for the design of IP rights and how these rights compare with other public policies aimed at promoting innovation.

2.1.2

Trade-offs in designing IP rights

IP rights are not discrete policy instruments. National policymakers face far-reaching choices on what can be protected by different IP instruments, which rights are conferred and the exceptions that may apply.[13]

As a first consideration, the effectiveness of different IP instruments depends on firms' absorptive and innovative capacity (see Box 2.2). Economic research has further shown that a firm's ability to profit from its innovation depends on access to complementary assets – such as manufacturing capability, organizational know-how and marketing skills.[14] These factors vary considerably across countries at different levels of economic development.

The design of IP rights needs to respond to the innovative potential of local firms. For firms in countries at an early stage of development, utility models may be more relevant than patents for protecting inventive output.[15] Several East Asian countries relied heavily on utility models in their early development stages – often protecting incremental, non-patentable modifications of imported products.[16] One study on the historical experience of the Republic of Korea found that the experience firms gained by using the utility model system prepared them for effectively using the patent system, both nationally and internationally.[17] However, other low- and middle-income countries with utility model systems in place have not seen a similar reliance on this form of IP. No systematic evidence is available to guide policymakers on the circumstances under which utility models work best.

13 As will be further discussed in Section 2.3, policymakers also face important choices in the design of institutions that administer and enforce patent rights.
14 See Teece (1986).
15 Utility models are sometimes also known as petty patents.
16 See Suthersanen (2006).
17 See Lee (2010).

Box 2.2: Absorptive and innovative capacity

The terms absorptive and innovative capacity refer to the set of conditions that enable firms to learn about existing innovation from external sources and to generate innovation themselves. The factors that determine a firm's capacity to absorb external information and to produce new ideas are related, but the concepts explain the different capabilities that firms require in order to successfully innovate.

Absorptive capacity was first used by economists Wesley Cohen and Daniel Levinthal in their seminal articles in 1989 and 1990 on the importance of firms undertaking R&D. They argue that conducting R&D generates two useful outcomes: new information and enhanced ability to assimilate and exploit existing information. When firms conduct R&D, they learn from the process and build technical skills. This, in turn, enables them to identify and assimilate R&D outcomes developed elsewhere, improve their technical knowledge and, later, their innovative capability, the ability to create new innovation.[18]

The ability to assimilate and learn from new knowledge is also relevant at the economy-wide level. Economies that are able to build sufficient absorptive capacity are more likely to benefit from exposure to foreign technologies and may, eventually, develop the ability to generate new technologies on their own.[19]

In economic theory, the design of IP rights has been treated as an optimization problem: governments adjust IP policy in order to maximize the net benefit that accrues to society from new inventions, taking into account the possibly adverse effects exclusive rights have on competition and follow-on innovation. Economist William Nordhaus first applied the optimization approach to setting the term of patent protection.[20] It can also be applied to the breadth of IP protection – as determined by the claims set out in IP titles and their interpretation by courts.[21]

In the actual design of IP rights, economic optimization arguably has played little direct role. This partly reflects the difficulty of empirically implementing an optimization model. The societal value of inventions is typically unknown before policies are set. In addition, fully capturing all the benefits and costs, as outlined in Subsection 2.1.1, seems elusive, even for the best-equipped economists.

Nonetheless, economic theory offers some useful guidance for policymakers. First is that IP protection standards should be differentiated according to the specific environment in which innovation takes place. This is partly reflected in actual IP policy by the fact that different IP instruments exist for different subject matters (see Table 2.1). For example, while a new tablet computer may be protected by patents, industrial designs and copyright, each IP right protects a distinct innovative element – whether it is the technology for operating a touch screen, the aesthetic feature of the tablet's design or the software running on it.

There is also important scope for fine-tuning the breadth of IP rights across different technology fields – partly through laws and partly through the actions of IP offices and courts. Economists have argued, for example, for differentiated patent breadth depending on the extent to which patented inventions in particular industries build on each other.[22] While some differentiation does indeed occur in practice, it is not clear whether it always follows economic considerations.[23]

18 See Cohen and Levinthal (1989, 1990).
19 See the works of Nelson (1993), Kim (1997), Yu (1998), the World Bank (2001) and Lall (2003).
20 See Nordhaus (1969).
21 See Scotchmer (2004) and Gilbert and Shapiro (1990).
22 For example, Jaffe (2000) argues that broader patent protection should be afforded to the initial invention in a line of cumulative inventions. See also Green and Scotchmer (1995), Scotchmer (1996) and O'Donoghue *et al.* (1998).
23 Lemley and Burk (2003) discuss how US patenting standards differ across industries and what motivates these differences.

The changing nature of innovation has challenged established norms on what subject matters can be protected by different IP instruments, especially in the area of patents. Historically, patents have been associated with technological inventions; the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement), for example, refers to inventions "in all fields of technology". However, the rise of non-technological inventions has raised questions about whether patents should also be granted for software, business methods or financial trading strategies, to name a few examples. From an economic perspective, arguably it matters less whether an invention is of a technological nature; what is more important is whether patent rights make a difference in resolving appropriability problems and contribute to the disclosure of knowledge that would otherwise remain secret.

Finally, in designing differentiated IP standards, certain trade-offs exist. Policymakers may not be sufficiently informed about innovation conditions to optimally differentiate IP policies. In addition, uniform IP standards are easier to operate, and political economy pressures to favor certain sectors are less likely to arise.

Moreover, policymakers need to be aware of how certain forms of IP may be chosen over others. In particular, firms face the choice of protecting inventions by patent rights or through trade secrecy. Surveys suggest that weak patent rights may prompt firms to rely more often on secrecy.[24] This enlarges opportunities for legitimate imitation and technology diffusion; however, where imitation is not possible, it may forestall the disclosure of valuable knowledge.[25]

2.1.3

How IP protection compares to other innovation policies

IP rights are a useful incentive mechanism when private motivation to innovate aligns with society's preferences with regard to new technologies. But such an alignment does not always exist. In addition, it is unclear whether the IP system can incentivize invention that is far from market application, for example basic science research. So, what other means do governments have to promote innovation, and how do they compare with the IP system?

In general, one can broadly distinguish three mechanisms for promoting innovation. First, there is publicly-funded innovation carried out by academic institutions and public research organizations. Second, governments can fund research undertaken by private firms – notably through public procurement, research subsidies, soft loans, R&D tax credits and innovation prizes. Third, the IP system is the one mechanism that promotes privately executed R&D which is financed through the marketplace rather than government revenues.[26]

24 See Mansfield (1986), Levin *et al.* (1987) and Graham and Sichelman (2008). These surveys show that firms – across many industrial sectors, except for the chemical and pharmaceutical sectors – relied more heavily on trade secrets than on patents to protect their innovation from rivals. They also show that firms producing process – rather than product – innovation rank trade secrets as more effective than patents in protecting innovation. This preference is also expressed where the likelihood of imitation is higher, such as where patent protection is perceived to be weak or the perceived value of innovation is high.

25 Lerner and Zhu (2007) show that a weakening of copyright protection in the US has prompted software developers increasingly to rely on patent rights. However, it is not clear from their study how this substitution of IP forms has affected innovation.

26 See, for example, David (1993).

It is important to recognize that the various instruments of innovation policy can be complementary. For instance, academic research sometimes results in patents and subsequent licensing for commercial development. Similarly, government support of privately undertaken research may result in IP ownership. However, it is useful to independently analyze and compare each policy instrument.

Table 2.2 offers an overview of the different mechanisms and compares them along several dimensions. It shows that the choice of policy instrument depends on the circumstances in which R&D is conducted. To begin with, basic research that does not immediately lead to commercial application is largely undertaken by academia and public research organizations. These institutions also invest in more generic research aimed at advancing specific societal interests – for example in the area of health. Other policy instruments can also spur such generic research, although they typically place a stronger emphasis on applied research.

Important differences exist in how R&D is financed. Certain policy instruments – notably, prizes, R&D tax credits and IP rights – require firms to initially fund R&D activity on their own or through financial markets. These instruments may therefore be less effective for large and highly risky R&D projects and in economies with underdeveloped financial markets (see Box 2.3). The other instruments provide upfront public financing of R&D, reducing ex-ante risk and avoiding the problems of imperfect credit markets.[27]

Box 2.3: Barriers to innovation in Chile

Chile is a small open economy that mainly exports raw materials and agricultural commodities – such as copper, wine, fruits and fish. Nonetheless, the country has incipient technological capabilities in certain industries, notably those linked to the processing of natural resources. Indeed, responses to Chile's national innovation survey reveal that 24.8 percent of firms had introduced some kind of innovation in the 2007-2008 period.

What barriers do Chilean firms encounter when they innovate? According to the same survey, high costs of innovative activity and difficulties in obtaining financing rank among the most important barriers. Firms also indicate "ease of copying by other firms" as a problem, but it only ranks 11th on the list of barriers. Accordingly, only 4.8 percent of innovating firms indicated that they had applied for patents – a figure far below similar shares for the United States (US) and European countries.

In response to these key barriers to innovation, one central element of Chile's innovation policy has been the provision of innovation subsidies. Two innovation funds – the *Fondo Nacional de Desarrollo Científico y Tecnológico* and the *Fondo de Fomento al Desarrollo Científico y Tecnológico* – offer support to basic scientific research and early stage R&D activity.

Source: Benavente (2011).

A closely related consideration is whether a policy instrument functions mainly as a "push" or a "pull" mechanism. The key difference is that, in the case of a "push" mechanism innovators are rewarded at the outset, whereas in the latter case, the reward depends on the innovation's success. "Pull" mechanisms such as IP rights and prizes may thus entail stronger performance incentives, as innovators face the pressure – or lure – of success when engaging in R&D.

27 For a literature survey, see Hall and Lerner (2010).

As mentioned earlier, one attraction of the IP system is that companies likely to be well-informed about technological opportunities select R&D projects themselves. This is also the case for tax credits. In order to obtain subsidies and soft loans, companies may initiate an R&D project, but it is a government agency that ultimately decides whether to support the project. In the case of procurement and innovation prizes, governments initiate and select R&D projects. This may give rise to so-called information failures. First, governments may be imperfectly informed about the success potential of competing R&D projects, possibly leading to less than ideal choices. Second, problems related to incomplete contracting may arise; in particular, it may be difficult at the outset to fully enumerate the conditions that determine whether a procurement contract or prize objective has been fulfilled.

The categorization presented in Table 2.2 ignores important choices in the design of individual policy instruments that affect innovation performance. However, it points to some of the key advantages and drawbacks of the IP system relative to other innovation policies. First, for governments, the IP system is cheap; it does not require government spending to finance R&D. Second, R&D decisions based on IP rights are decentralized, reducing information failures. Tax credits offer the same advantage, but do not by themselves solve the appropriability problem. In fact, for tax credits to be effective, firms need to be able to appropriate innovation investment – including through IP rights.

One drawback of the IP system is that it leads to exclusive rights over research outcomes; this may reduce competition and slow cumulative innovation. Innovation prizes that result in public ownership of research results are superior in this respect, and they preserve the "pull" property of the IP system. However, they can suffer from information failures, notably the difficulty of writing complete contracts. This may explain why innovation prizes have mainly been used for relatively small-scale problems for which solutions are within reach, and mainly by firms rather than governments (see subsection 1.2.5). Nonetheless, prizes may be especially suitable for incentivizing socially desirable innovation for which no or only small markets exist, precisely because of the lack of market signals that may otherwise guide R&D decisions.[28]

A second drawback of IP rights – and prizes – is that they require *ex-ante* private financing of R&D. In environments where such financing is hard to come by, "push" instruments such as subsidies and soft loans may be needed to encourage innovation, especially where risk is involved.

In sum, no single policy instrument works best in all circumstances. In considering which instrument to employ, policymakers need to take into account financing conditions, risk levels, possible information failures, performance incentives and other variables. Indeed, since each policy instrument has both advantages and drawbacks, the key challenge for policymakers is to mix policies so that they effectively complement each other.

28 Much thought has been given in recent years to designing innovation prizes in a way that maximizes their effectiveness, especially in the pharmaceutical sector. For example, see Love and Hubbard (2009) and Sussex *et al.* (2011).

Table 2.2: Overview of innovation policy instruments

	Main features	Research direction	Financing of R&D	Push versus pull	Selecting entity	Selection criteria	Ownership of results	Main advantages	Main drawbacks
Publicly funded and executed									
Public research organizations	• Public goods such as defense and health • Does not undertake commercialization of knowledge	• Basic • Generic	• *Ex-ante* financing of project cost	• Push	• Government	• Public interest • Peer review	• Public • Institution	• Advance fundamental scientific knowledge	• Uncertain impact
Academic research	• Aimed at increasing basic scientific knowledge • Does not undertake commercialization of knowledge	• Basic • Generic	• *Ex-ante* financing of project cost	• Push	• Government • University • Philanthropy	• Public need • Peer review	• Public • Institution	• Advance fundamental scientific knowledge	• Uncertain impact
Publicly funded and privately executed									
Procurement	• Government purchases of well-defined innovative goods – for example, military equipment	• Generic • Applied	• Financing of project cost • Timing depends on contract	• Combination of push and pull depending on design	• Government	• *Ex-ante* competition	• Depends on contract	• Mobilizes competitive market forces for the provision of public good	• Difficult to write perfect contracts
Research subsidies and direct government funding	• Public support for targeted research	• Generic • Applied	• *Ex-ante* financing based on estimated project cost	• Push	• Government • Firm	• Competition • Administrative decision	• Usually firm	• Mobilizes competitive market forces for public benefit	• Governments are imperfectly informed about success potential of R&D projects
Prizes	• Prizes for targeted solutions to specific problems	• Generic • Applied	• *Ex-post* financing based on ex-ante estimated project cost	• Pull	• Government	• Competition	• Usually public	• Mobilizes competitive market forces for public benefit • Subsequent competitive provision of technology	• Difficult to write perfect contracts • Requires private *ex-ante* financing of R&D
Soft loans	• Subsidized provision of credit through below-market interest rates, government guarantees and flexible reimbursement provisions	• Applied	• *Ex-ante* financing based on estimated project cost	• Push • Some pull depending on design	• Government • Firm	• Administrative decision	• Firm	• Reduces risks associated with large R&D undertakings	• Governments are asymmetrically informed about success potential of R&D projects • Does not address firms' appropriability problem
R&D tax credits and related fiscal incentives	• Reduced taxation of profits linked to investment in R&D	• Generic • Applied	• *Ex-post* financing dependent on actual investment expenditure	• Push • Some pull depending on design	• Firm	• Proof of R&D investment	• Firm	• Decisions on R&D decentralized	• Does not address firms' appropriability problem • Requires private *ex-ante* financing of R&D
Privately funded and executed									
IP rights	• Market exclusivity	• Generic • Applied	• *Ex-post* financing based on market value of innovation	• Pull	• Firm	• As specified in IP laws	• IP owner (firm or institution)	• Decisions on R&D decentralized	• Static misallocation of resources • Requires private *ex-ante* financing of R&D

Source: WIPO, extending on Guellec and van Pottelsberghe de la Potterie (2007) and Granstrand (1999, 2011).

2.2

Taking a closer look at the patent system

The last three decades have seen use of the patent system increase to historically unprecedented levels (see Figure 1.18). They have also seen substantial increases in real R&D investment and remarkable progress in many areas of technology – most spectacularly in the information and communications technology (ICT) field. While these trends indicate that patenting has become more central to strategies of innovative firms, they alone do not reveal how effective the patent system has been in promoting innovation and improving welfare.

Prompted by the increase in patenting activity, economists have scrutinized the role that patents play in the innovation process. In addition, the construction of new databases – often combining unit record data on patents with firm-level information on innovative behavior and economic performance – has enabled richer investigations into the effects of patent protection.

This section takes a closer look at the economics of the patent system, focusing on more recent research. It expands on several concepts and ideas introduced in the previous section and confronts them with empirical evidence. In particular, it discusses how effective the patent system is as an appropriation mechanism in different sectors of the economy (Subsection 2.2.1), how more widespread patenting affects the process of cumulative innovation (Subsection 2.2.2), how patent rights shape the interplay between competition and innovation (Subsection 2.2.3) and the role patents play in modern technology markets and open innovation strategies (Subsection 2.2.4). The insights gained through more recent research have led economists to refine their views on the role the patent system plays in the innovation process.

2.2.1

How patent protection affects firm performance

As a first step, it is helpful to review the evidence on how patent protection affects the performance of firms. Subsection 2.1.1 pointed to one key difficulty in generating empirical evidence: since patent systems have been in place in most countries throughout recent history, no obvious benchmarks exist against which the performance of patenting firms can be compared. One way around this problem is to directly survey firms about the importance they place on patents as an appropriation mechanism for innovative activity. Several such surveys have been conducted, and Table 2.3 summarizes their main results.

As pointed out in Section 2.1, both lead time and sales and service activities emerge as the most important appropriation mechanisms. The importance of patents varies across industries. In industries with short product life cycles – for example, electronics – patents appear to be of lesser importance; indeed, technologies may be obsolete by the time patents are granted. By contrast, patent protection is critically important in the chemical and pharmaceutical industries. This results from the long R&D process in these industries, combined with the fact that chemical and pharmaceutical products are easily imitated once introduced to the market. The surveys summarized in Table 2.3 provide useful insights into the role of patent protection, but the evidence is qualitative in nature.

Table 2.3: Summary of survey evidence

Survey	Year	Country	Survey sample	Product innovation					Process innovation				
				1	2	3	4	5	1	2	3	4	5
Yale	1982	US	Firms (publicly traded), performing R&D in the manufacturing sector	Sales or service efforts	Lead time	Fast learning curve	Patents	Secrecy	Lead time	Fast learning curve	Sales or service efforts	Secrecy	Patents
Harabi	1988	Switzerland	Firms engaging in R&D, mainly in manufacturing sector	Sales or service efforts	Lead time	Fast learning	Secrecy	Patent	Lead time	Sales or service efforts	Fast learning	Secrecy	Patents
Dutch CIS	1992	Netherlands	Firms (≥10 employees) that developed or introduced new or improved products, services or processes during the last three years in the manufacturing sector	Lead time	Retain skilled labor	Secrecy	Patent	Complex-ity of design	Lead time	Retain skilled labor	Secrecy	Complex-ity of design	Certifi-cation
Carnegie Mellon	1994	US	Firms (≥ 20 employees and ≥ USD 5 million in sales) performing R&D in the manufacturing sector	Lead time	Secrecy	Comple-mentary assets	Sales or service efforts	Patent	Secrecy	Comple-mentary assets	Lead time	Sales or service efforts	Patents
Japan Carnegie Mellon	1994	Japan	Firms performing R&D (≥ JPY 1 billion capitalization) in the manufacturing sector	Lead time	Patents	Comple-mentary assets	Sales or service efforts	Secrecy	Comple-mentary assets	Secrecy	Lead time	Patents	Sales or services assets
RIETI-Georgia Tech	2007	Japan	Inventors who applied for triadic patents with priority years 2000-2003	Lead time	Comple-mentary assets	Secrecy	Comple-mentary assets	Patents	Survey does not distinguish between product and process innovation				
Berkeley	2008	US	Small manufacturing firms focusing on biotechnology, medical devices and software	Lead time	Secrecy	Comple-mentary assets	Patents	Reverse engi-neering difficult	Survey does not distinguish between product and process innovation				

Source: WIPO extending on Hall (2009). Results of the surveys were collected for Yale (Levin *et al*., 1987), Switzerland (Harabi, 1995), Dutch CIS (Brouwer and Kleinknecht, 1999), Carnegie Mellon (Cohen *et al*., 2000), Japan Carnegie Mellon (Cohen *et al*., 2002), RIETI-Georgia Tech (Nagaoka and Walsh, 2008), Berkeley (Graham *et al*., 2009).

Several studies have sought to generate quantitative evidence on the importance of patent protection. One study by Arora and his co-authors (2008) employs detailed data on firms' innovative activity and patenting behavior to estimate a so-called patent premium – defined as the increment to the value of an invention due to having it patented. The study's methodology takes into account that patenting decisions are not random: firms only seek to patent inventions that can be expected to yield a net benefit. The results indicate a premium of almost 50 percent for patented inventions.[29] Confirming the earlier survey evidence, patent premia are highest in the fields of medical instruments, pharmaceuticals and biotechnology and lowest in the food and electronics sectors. The results also show that patent premia are higher for larger firms; one likely explanation for this finding is that larger firms are better equipped to exploit and enforce patents than smaller firms.[30]

29 Arora *et al.* (2008) estimate a negative patent premium for all innovation – including innovative technologies that firms do not actually patent. This suggests that the costs of patenting – in the form of the possible disclosure of knowledge that would otherwise be kept secret – exceed its benefits for many innovations.

30 Patent renewal models also offer insight into the private value firms derive from having their inventions protected by patents. Important studies in this field include Pakes (1986), Schankerman and Pakes (1986), Lanjouw *et al.* (1998) and Schankerman (1998). However, these studies do not offer a direct estimate of the R&D-incentive effect associated with patent protection.

Studies have also investigated whether the prospect of securing patent rights leads firms to invest more in R&D. A study by Qian (2007) focuses on the experience of 26 countries that introduced pharmaceutical patent protection in the period 1978-2002. The pharmaceutical sector is especially suited for analyzing how patent protection affects R&D behavior. The survey evidence summarized in Table 2.3 reveals the importance of patent protection in this sector, and the establishment of pharmaceutical product patent protection typically represents a major policy shift. The study finds no effect for patent protection across all countries, but a positive effect in countries that are more developed and have higher levels of education. This finding highlights the fact that pre-existing innovative capacity is an important factor in whether patent rights matter (see Subsection 2.2.2).

A closely related study by Kyle and McGahan (2011) draws similar conclusions. In addition, it finds that the introduction of patent protection in lower-income countries has not created incentives for R&D related to diseases primarily affecting those countries. The study argues that this result is due to the small size of these countries and calls for complementary innovation policies to incentivize R&D specific to the needs of poorer societies (see Subsection 2.2.3).[31]

A related question concerns whether differences in the level of patent protection across countries affect firms' decisions on where to locate R&D. Such differences may be of minor importance for R&D directed at global markets. However, R&D often has a local component – for example, where firms adapt technologies to local markets or focus on the preferences and needs of local consumers.

Thursby and Thursby (2006) studied the importance of IP protection in the decision-making process of R&D-intensive multinational firms. In a survey of 250 such firms, respondents identified IP protection as an important factor in determining where to conduct R&D. However, they still established R&D facilities in markets where IP protection was perceived to be weak. Indeed, other factors – notably, the potential for market growth and the quality of R&D personnel – emerge as important drivers of location decisions. Further research work by Thursby and Thursby (2011) highlights the fact that most "new-to-the-world" research is conducted either in the US or in other high-income countries where IP protection tends to be strong. Again, however, IP protection does not appear to be the main driver of this outcome; university faculty expertise and ease of collaboration with universities emerge as the key factors which explain where firms carry out cutting-edge research.

31 The evidence from other studies is more ambiguous, although many use a less convincing policy counterfactual. Park and Ginarte (1997) and Kanwar and Evenson (2003) use an index that measures overall strength of a country's IP rights. They also find that patent protection leads to greater R&D expenditure for countries above certain levels of development. Sakakibara and Branstetter (2001) studied the effects on R&D of Japan's 1988 patent reform and find only a small impact on R&D activity.

Recognizing that patents can convey information about the commercial potential of inventions, economists have studied their role in mobilizing financial resources for innovative firms. Indeed, studies have found that firms that own patents are more likely to receive financing from venture capitalists than those that do not. Recent surveys conducted in the US show that this is the case for small rather than large firms.[32] Two important studies on venture capital financing of US semiconductor firms show that not only do patent applications convey important information to investors about the quality of inventions, they also help firms to attract funds in the earlier stages of financing.[33] At the same time, the importance of patents in facilitating access to finance differs by industry, with, for example, patents playing a more prominent role in health care-related technologies than ICTs.[34]

2.2.2

How patent strategies shift where innovation is cumulative

To understand how patent protection affects innovation, it is essential to look beyond the individual firm. Innovative activity seldom happens in isolation; one firm's solution to a problem typically relies on insights gained from previous innovation. Similarly, in competitive markets, firms innovate simultaneously and develop technologies that may complement each other. As pointed out in Subsection 2.1.1, patent rights influence how prior or complementary knowledge can be accessed and commercialized.

The rapid increase in the number of patent filings has raised concerns about patents hindering cumulative innovation. Indeed, patenting activity has grown especially fast for so-called complex technologies. Economists define complex technologies as those that consist of numerous separately patentable inventions with possibly widespread patent ownership; discrete technologies, by contrast, describe products or processes made up of only a few patentable inventions. Figure 2.1 depicts the growth in patent applications worldwide for these two technology categories. The top figure compares patenting growth for first filings, approximating new inventions; it shows consistently faster filing growth for complex technologies since the early 1970s. The bottom figure focuses on subsequent filings, made up mostly of filings outside the applicants' home country; it reveals equally faster filing growth for complex technologies, though only starting from the mid-1990s.

32 See Lemley (2000), Hsu and Ziedonis (2008), Harhoff (2009), Graham and Sichelman (2008) and Sichelman and Graham (2010).

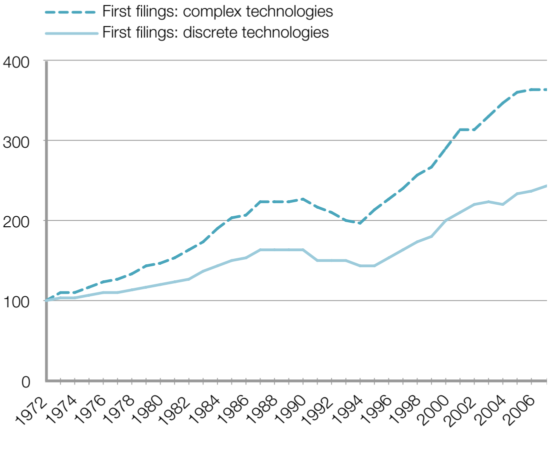
33 Cockburn and MacGarvie (2009) examine how US legislation enabling the patentability of software in the mid-1990s has affected market entry of new competitors. They use data on the financing of entrants in 27 narrowly defined software markets. One of their findings is that firms with patents are more likely to be funded by venture capitalists. See also Greenberg (2010).

34 See Graham *et al.* (2009). This study also suggests that the role of patents differs according to financing source.

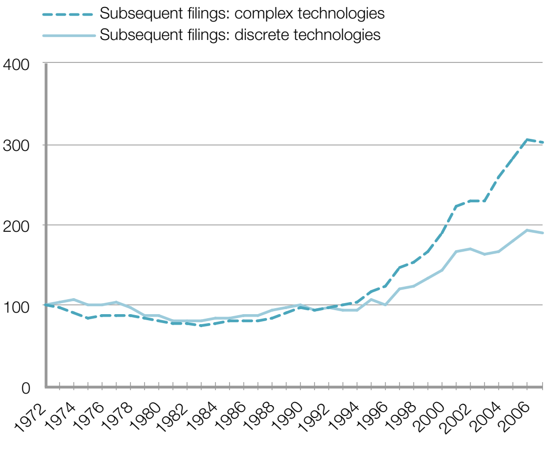
Figure 2.1: Complex technologies see faster patenting growth

Patent filings for complex versus discrete technologies, 1972=100, 1972-2007

First filings



Subsequent filings



Note: WIPO's IPC-Technology Concordance Table is used to classify the data by field of technology. The classification of complex and discrete technologies follows von Graevenitz *et al.* (2008).

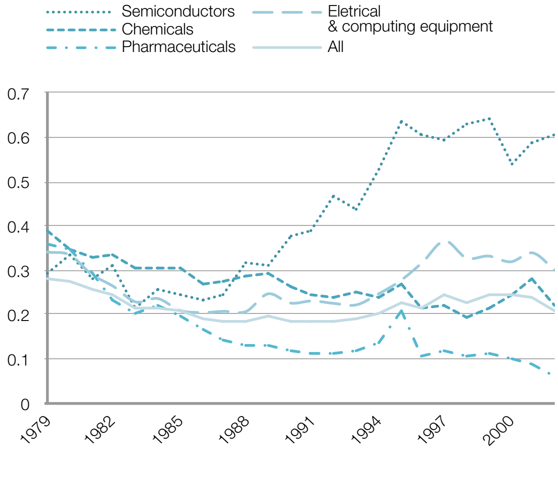
Source: WIPO Statistics Database, March 2011.

What accounts for the difference in growth rates? The difference may partly reflect the nature of technological change. For example, complex technologies include most ICTs which have experienced rapid advances over the past three decades. However, economic research suggests that faster growth in complex technologies is also due to a shift in patenting strategies.

Hall and Ziedonis (2001) convincingly made this point in their study of patenting behavior in the US semiconductor industry. Firm surveys such as the ones outlined in Table 2.3 show that patents are among the less effective mechanisms for appropriating returns on R&D in this sector; because of short product life cycles, semiconductor firms mainly rely on lead time advantage and trade secrets to recoup their investment in innovation. Paradoxically, however, the US saw a sharp increase in semiconductor patenting from the mid-1980s to the mid-1990s. Moreover, semiconductor patenting grew at a faster pace than real R&D investment, leading to a doubling of the so-called patent yield (see Figure 2.2).

Figure 2.2: Semiconductor patenting grows faster than R&D investment

Patent yield in selected US manufacturing industries, 1979-2002



Note: Patent yield is defined as the ratio of patents granted to constant dollar R&D investment. It is based on a sample of publicly listed firms for which R&D data are available through Compustat. Chemicals exclude pharmaceuticals and electrical and computing equipment excludes semiconductors.

Source: Updated from Hall and Ziedonis (2001).

Hall and Ziedonis relate the increase in semiconductor patenting to shifts in the US legal environment that proved favorable to patent owners. Relying on econometric analysis of firm-level data and interviews with semiconductor firms, they conclude that these shifts prompted firms to proactively build up large patent portfolios. One motivation for such portfolios is to ensure a firm's freedom to operate in its innovation space and preempt litigation. In fact, the study finds that the large-scale and capital-intensive manufacturers most vulnerable to holdup – for example, through preliminary injunctions – invested most aggressively in securing patent rights. A second motivation for creating these portfolios is to strengthen a firm's bargaining position vis-à-vis its competitors. In particular, a firm owning many patents in a crowded technology space can preempt litigation by credibly threatening to countersue competitors. In addition, it is in a better position to negotiate favorable cross-licensing arrangements that are often needed to commercialize new technologies.[35]

How widespread is strategic patenting beyond the US semiconductor industry? Clearly, patent portfolio races have been documented for other complex technologies – ICTs in general and, in particular, telecommunications, software, audiovisual technology, optics and, more recently, smartphones and tablet computers.[36] While the Hall-Ziedonis study focused on the US, evidence suggests that electronics firms in other countries – especially in East Asia – have also built up large patent portfolios for strategic purposes.[37] According to one study, a 1986 lawsuit by semiconductor firm Texas Instruments against Samsung – which led to a settlement worth more than USD 1 billion – proved to be a catalyst for Korean firms to proactively build up their patent portfolios.[38] Still, looking at trends in patent filings and real R&D expenditure, the US stands out as the only major jurisdiction that has seen a consistent increase in the economy-wide patent yield since the mid-1980s.[39] While other factors may account for this diverging trend, it is consistent with the conclusion of Hall and Ziedonis that patent portfolio races were prompted by changes in the US legal environment.[40]

What is the ultimate effect of strategic patenting behavior on welfare and innovation? On the one hand, such behavior has not obviously prevented rapid progress in semiconductors and many other complex technologies – though the counterfactual scenario remains, of course, unclear.[41] In addition, the study by Hall and Ziedonis points out that patent protection fostered specialization in semiconductor innovation; in particular, patent rights facilitated the entry of specialized semiconductor design firms which initially had relied on venture capital finance.[42]

35 For survey evidence on the importance of patent ownership for negotiating cross-licensing arrangements, see Cohen *et al.* (2000) and Sichelman and Graham (2010).

36 See Harhoff *et al.* (2007) and, for software, Noel and Schankerman (2006). In the case of smartphones, evidence is still anecdotal in nature – see "Apple and Microsoft Beat Google for Nortel Patents" in The New York Times (Nicholson, 2011).

37 See Cohen *et al.* (2002).

38 See Lee and Kim (2010).

39 See WIPO (2011a), measuring patent yield as first filings over real R&D expenditure. Similarly, Switzerland and the Netherlands have seen a rise in patent yield since the early 1990s. The Republic of Korea experienced a rising patent yield from 1994 to 2000, but that measure has since fallen.

40 However, survey evidence suggests that strategic use of patents is more prevalent in Japan than in the US (Cohen *et al.*, 2002).

41 To the extent that large patent portfolios can be said to "neutralize" each other, the costs of acquiring and administering them may, from an economy-wide perspective, be considered wasteful.

42 See also Arora *et al.* (2001a) and Arora and Ceccagnoli (2006) for similar evidence beyond the semiconductor industry.

On the other hand, econometric evidence suggests that dense webs of overlapping patent rights – so-called patent thickets – can indeed slow or even forestall cumulative innovation processes.[43] High transaction costs have made it difficult for some – especially small – firms to obtain the licenses necessary for prior and complementary technologies; the latter include patented research tools that, for example, are of special relevance to biotechnology research.[44] As will be further discussed in Chapter 3, private collaborative arrangements can, to some extent, preempt such adverse outcomes.

Finally, strategic patenting affects the nature and intensity of competition in product markets, in turn affecting innovation incentives. To understand precisely how first requires a broader discussion of the interaction between the forces of competition and innovation.

2.2.3

How patent rights shape the interplay between competition and innovation

Competition in product markets affects innovative behavior in different ways. Subsection 2.1.1 discussed one such way: if firms cannot generate profits above competitive levels, they cannot recoup their initial R&D investment. Too much competition harms innovation. Indeed, this relationship appears to hold empirically; studies show that, across industries, more intense competition is associated with less innovation. However, this correlation only holds above a certain threshold of competition. Below that level, more intense competition is actually associated with increasing innovation.[45] This latter finding has an intuitive explanation: if firms generate large economic rents and face little competition that threatens these rents, market pressure to innovate is weak. If, by contrast, firms' economic rents are threatened by rival innovative efforts, their incentive to innovate on their own is stronger.

Overall, there is thus an inverted-U-shaped relationship between competition and innovation, whereby investment in innovation first increases with the level of competition, and then declines as competition intensifies beyond that level. Although intuitive, formally incorporating these relationships into theoretical models of industrial organization has turned out to be difficult. Only recently have economists developed models that generate the inverted-U relationship observed in the data.[46]

How do patent rights influence the competition-innovation relationship? On the one hand, one may argue that patent rights foster a healthy competitive balance. They prevent competition of the free-riding type that undermines the appropriation of R&D investment. But they permit competition between substitute products each of which may be protected by different patent rights. In addition, certain features of the patent system directly promote competitive market forces: the disclosure requirement enables firms to learn from the inventions of rivals; and

43 See Cockburn *et al.* (2010) for econometric evidence.

44 See Eisenberg (1996), Heller and Eisenberg (1998), Murray and Stern (2006, 2007) and Verbuere *et al.* (2006).

45 See Aghion *et al.* (2005).

46 *Idem.*

the limited protection term ensures that the economic rent associated with a patent is time-bound, inducing firms to stay ahead by constantly innovating.

On the other hand, patent ownership can, in certain situations, significantly curtail competition. While rare, patent rights to key technologies for which few substitutes exist can lead to concentrated market structures. In addition, the emergence of patent thickets, as outlined in the previous subsection, can negatively affect competition by marginalizing those firms that do not have a sufficiently large patent portfolio as a bargaining tool. Where patent rights overly restrict competition, society loses twice: through higher prices and less choice in product markets; and through insufficient competitive pressure on firms to innovate. In practice, it is difficult for policymakers to assess when such a situation arises. There is little empirical guidance on what "dose" of competition is optimal for innovation. Indeed, this will differ across industries and depends on the characteristics of markets and technologies.

Nonetheless, policymakers should be especially concerned about two types of patenting practices. First, certain patenting strategies primarily serve to slow the innovative efforts of rival firms. For example, a firm may seek a patent for a technology that it does not commercialize, but may then sue rivals on the basis of that patent to block entry into product markets.[47] Indeed, a recent inventor survey revealed that, for nearly one-fifth of patents filed at the European Patent Office (EPO), "blocking competitors" was an important motivation for patenting.[48]

A related strategy involves filing patents with broad claims for trivial inventions and threatening competitors with litigation; even if the patent office eventually rejects those patents, they may generate uncertainty among rival firms who fear that their own innovative activity may clash with future patent rights. Small firms and new market entrants – often thought to be an especially important source of innovation in the economy – may be especially vulnerable to these types of blocking strategy, because they may not have a large enough patent portfolio to deter litigious rivals.

The rise in patenting of complex technologies has arguably widened the scope for using patents anticompetitively. Identifying such practices is difficult. Patent documents alone do not offer any insight into the strategic use of patent rights.[49] In addition, the line between a patent that aims to ensure freedom-to-operate versus a predatory patent may not be easily drawn, especially in industries with dense patent thickets. As will be further explained in Section 2.3, sound patent institutions can reduce the potential for patents to be used anti-competitively. In addition, there is an important role for competition policy to play in containing outright predatory behavior by patent owners.[50]

A second area of emerging concern relates to the activities of so-called non-practicing entities (NPEs). These entities are either individuals or firms that build up portfolios of patent rights, but do not seek to develop or commercialize any products based on technologies they own. Instead, they monitor markets for potentially infringing products and then enforce their patent rights by approaching firms to negotiate licenses or by initiating litigation. Many larger NPEs do not file patents themselves, but buy unused patents from firms that do not actively use them or that are forced by bankruptcy to auction them.

47 See Gilbert and Newbery (1982) for a theoretical exposition.

48 See Giuri *et al.* (2007).

49 However, Harhoff *et al.* (2007) argue that acts of predation will leave traces in patent data if those acts involve patent opposition or outright litigation.

50 See Harhoff *et al.* (2007).

NPEs can be beneficial to society by helping to create secondary markets for technology (see also the discussion in Subsection 2.2.4). Such markets can foster innovation incentives as they enable firms to reap a return on research activity, even if the resulting research output is not further developed and commercialized. Selling non-essential patents may be especially attractive for small companies or individual inventors that lack the resources to effectively use or enforce them.[51]

Yet, critics of at least some NPEs argue that their activities are primarily rent-seeking and that any benefit to the original patent owners is more than offset by the costs to the innovators targeted by NPEs' enforcement actions.[52] A firm threatened with costly litigation may prefer to settle and agree to pay a royalty, even if it feels that it has not infringed a patent. Since NPEs do not manufacture and thus do not risk infringing someone else's patent, they face no chance of counter-lawsuits. According to critics, NPEs are thus harmful to society, as they increase the risks associated with and cost of innovation.

Empirical research on NPEs is still in its infancy. One recent study on litigation of financial patents in the US finds that parties other than the inventor or the original patent applicant play a significant role in litigation. Patent owners initiating litigation fitted the profile of NPEs; they were overwhelmingly individuals or small companies – unlike the larger financial institutions that commercialize most financial innovations. Indeed, the latter were disproportionately targeted in litigation. The study also finds that financial patents were litigated at a rate of 27 to 39 times greater than that of US patents as a whole.[53] These findings are specific to the US financial service industry and do not shed light on how litigation has affected financial innovation. However, they point to NPEs as a rising force that innovating companies need to take into account.

As in the case of anti-competitive patenting strategies, sound patent institutions can make a difference in containing the possibly abusive behavior of NPEs that is detrimental to innovation – as will be further discussed in Section 2.3.[54]

2.2.4

The role patents play in technology markets and open innovation strategies

Chapter 1 discussed the rise of so-called technology markets, as reflected, for example, in more frequent patent licensing. At first, the existence of such markets may seem surprising. Technologies are highly specialized and non-standardized goods; matching sellers and buyers can be difficult – not least because many firms keep their technologies secret. Even where there is a match, strategic behavior and high transaction costs can prevent firms from entering into licensing contracts.[55] What then motivates firms to participate in technology markets and why are they increasingly doing so?

Subsection 2.1.1 pointed to one important reason: technology markets allow firms to specialize. Firms may be both more innovative and efficient by focusing on selected research, development or manufacturing tasks – outweighing the difficulties related to participating in technology markets. In addition, so-called general purpose technologies (GPTs) – technologies that find application in a large number of product markets – are often best developed by specialized firms who can sell them to many downstream firms, thereby recovering large upfront R&D outlays.[56]

51 See, for example, Geradin *et al.* (2011).
52 See, for example, Lemley and Shapiro (2007).
53 See Lerner (2010).
54 Some governments have also launched special initiatives aimed at limiting the exposure of innovating companies to NPE lawsuits. For example, in 2010 the Korean government helped launch a firm called Intellectual Discovery, which buys out patents that might be asserted against Korean firms. See "The Rise of the NPE" in Managing Intellectual Property (Park and Hwang, 2010).
55 See, for example, Nelson and Winter (1982), Teece (1988), Arora *et al.* (2001b) and Arora and Gambardella (2010).
56 See Bresnahan and Gambardella (1998) and Gambardella and McGahan (2010).

As discussed in Chapter 1, specialization is one important element of open innovation strategies: firms license out those technologies that are outside their core business; and they license in technologies that amplify their competitive advantage. Evidence confirms that firms that do not have the complementary assets needed to bring their inventions to market tend to license them to others for commercialization.[57] In addition, survey studies reveal that licensing is one of the main reasons for seeking patents in the US.[58] In Europe, one in five companies licenses patents to non-affiliated partners, while in Japan more than one in four companies do so.[59] Studies on GPTs, in turn, have shown that licensing is more likely to occur where downstream product markets are fragmented.[60] There is also evidence that certain industries – notably, the biotechnology, semiconductor and software sectors – have seen an increase in specialized firms.[61]

Little is known, however, about the fundamental factors that have driven greater specialization in more recent history. One possible explanation is that smaller companies with fewer bureaucratic structures may be better positioned to find solutions to increasingly complex technological problems. Another reason may be that ICTs and new business models have made it easier for specialized firms to participate in technology markets. Subsection 1.3.3 described, for example, the entry of new intermediaries with novel approaches to matching technology sellers and buyers.

A second reason why firms participate in technology markets is to tap these markets for valuable knowledge. In-house research is an essential element of innovation, but firms advance their knowledge and draw inspiration from the ideas of others. Economists have devised the concept of knowledge spillovers to describe situations in which knowledge flows from one firm or individual to another, without the originator receiving any direct compensation. From society's viewpoint, knowledge spillovers are desirable, because they lead to the wide dissemination of new ideas. However, if knowledge spills over to everyone as soon as it is created, the classic appropriability dilemma arises. A trade-off exists, for policymakers and firms.

Policymakers must balance incentives for creating knowledge against the rapid diffusion of knowledge. The patent system helps to strike this balance by granting limited exclusive rights to inventors while, at the same time, mandating the disclosure of information on inventions to society. Inventor surveys reveal that published patents are indeed an important knowledge source for firms conducting R&D – more so in Japan than in the US and Europe.[62] No study has attempted to quantify the associated knowledge spillovers and their economic benefits. Such an exercise might indeed be elusive. Yet, the patent literature represents a valuable source of knowledge for creative minds anywhere in the world. In addition, the easy availability of millions of patent documents to anyone connected to the Internet has arguably created new catch-up opportunities for technologically less developed economies.

Firms face a similar trade-off between guarding and sharing knowledge. On the one hand, they need to earn a return on their R&D investment, which calls for preventing knowledge from leaking to competitors. On the other hand, absolute protection of ideas is not possible and, more important, it may not even be desirable. Spillovers are often a two-way street, involving give and take. For example, economic research shows that innovating firms have found it beneficial to collocate; being close to firms operating in the same field brings learning benefits even if it means sharing one's own knowledge.[63]

57 Using the 1994 Carnegie Mellon survey on industrial R&D in the US, Arora and Ceccagnoli (2006) found that firms that do not have specialized complementary assets for commercializing their inventions are more likely to license out their inventions than those who do.
58 See Cohen *et al.* (2000) and Sichelman and Graham (2010).
59 See Zuniga and Guellec (2009).
60 See Gambardella and Giarratana (2011) and Arora and Gambardella (2010).
61 See Arora *et al.* (2001a), Hall and Ziedonis (2001) and Harhoff *et al.* (2007).
62 See Nagaoka (2011) and Gambardella *et al.* (2011).
63 See Krugman (1991).

Generating spillovers is a second important element of open innovation strategies: firms can be better innovators by engaging with others – even if that involves some sharing of proprietary knowledge. Indeed, patent rights are at the heart of the trade-off between guarding and sharing knowledge. They allow firms to flexibly control which technologies to share, with whom and on what terms. Economic research provides only limited guidance on how different patent-based knowledge sharing activities – especially those associated with more recent open innovation strategies – affect spillovers and innovation. As described in Subsection 1.3.2, this is partly the result of insufficient data; in particular, patent licenses are often confidential and escape statistical measurement. Box 2.4 summarizes evidence on one open innovation initiative in the area of green technologies, and finds systematic differences between the technologies that firms are willing to share and those they keep in-house.

Box 2.4: Open Innovation and the Eco-Patent Commons

Recognizing the need for promoting innovation and the diffusion of green technologies, in 2008 a number of multinational companies – including IBM, Sony and Nokia – created an "Eco-Patent Commons". This initiative allows third parties royalty-free access to patented technologies, voluntarily pledged by firms from around the world. One key aim of the Commons is to encourage cooperation and collaboration between pledging firms and potential users to foster further joint innovation.

A recent study by Hall and Helmers (2011) analyzed the characteristics of the 238 patents pledged to the Commons. In particular, it compared patents pledged to: i) patents held by pledging firms that are not donated to the Commons; and ii) a randomly drawn set of patents in the same technology field.

Approximating patent value by indicators such as patent family size and patent citations received, the study finds that patents in the Commons are more valuable than the average patent held by pledging firms and than comparable patents protecting similar technologies. However, patents pledged do not seem to cover firms' most radical inventions. In addition, they do not appear to be at the core of firms' patent portfolios, possibly explaining their willingness to place them in the Commons. While these findings offer interesting insights into firms' open innovation strategies, it is too early to assess how successful the Commons is at promoting further green innovation.

Finally, a third important reason why firms participate in technology markets and adopt open innovation strategies is to access complementary skills and technologies. A firm may find that it stands to gain by collaborating with another firm or a university in developing a particular technology. In other cases, a firm may require access to proprietary technologies held by other firms in order to commercialize a product – a frequent scenario in technology fields in which patent thickets proliferate (see Subsection 2.2.2). How technology markets operate when firms cooperate with each other or with universities will be discussed more fully in Chapters 3 and 4.

2.3

Appreciating the role of patent institutions

Patent laws set the basic rules on what can be patented, for how long and under what conditions. However, the incentives created by the patent system are critically dependent on how these rules are implemented. This is largely the responsibility of patent offices and courts. For a long time, economic research paid little attention to these patent institutions. This, arguably, has changed – partly because unprecedented levels of patenting have put these institutions under considerable pressure.

This section seeks to highlight the important role played by patent institutions. It first discusses the characteristics of sound patent institutions. It then focuses on how patenting trends over the past decades have challenged many patent offices and what choices they face.

2.3.1

What makes for sound patent institutions

Patent institutions best serve innovation when they promote two broad principles: rigorous examination leading to the grant of quality patents and balanced dispute resolution.

Promoting the first principle has two important elements. First, patent offices should grant patents only for those inventions that strictly meet the standards of patentability – namely, novelty, inventive step and industrial applicability. This sounds straightforward, but for patent offices it is not: the complexity of technology is constantly on the rise and many entities in different parts of the world create new knowledge that may be relevant prior art. Second, patent documents should clearly delineate the patent's inventive claims and describe the invention in a transparent way. Patents granted which meet both criteria can be considered quality patents.[64]

The second principle recognizes that disputes over patent rights invariably occur. But when they do, they should be resolved in a way that balances the interests of all parties involved. In particular, the parties should have easy access to dispute resolution mechanisms, but those mechanisms should minimize bad faith initiation of disputes and remedies should be proportionate to any damage suffered.

Why do these two principles matter? Poor-quality patents – including patents for trivial inventions or those with overly broad or ambiguously drafted claims – can harm innovation. At worst, they may lead firms to refrain from certain research activities or from commercializing a new technology for fear of violating patent rights; at best, they burden innovating companies by leading to extra royalty payments and legal costs.[65] Poor-quality patents may also increase the risk of anticompetitive uses of patent rights (see Subsection 2.2.3). Vague descriptions of inventions in patent documents, in turn, may curtail the spillover benefits of patent disclosure.

64 Quality is here defined in terms of the rigor of the examination process, not in terms of the technical or commercial value of the invention.

65 See Choi (1998), Jaffe and Lerner (2004), Lemley and Shapiro (2005) and Harhoff (2006).

Imbalanced dispute resolution can have more varied effects on innovative behavior. For example, if dispute resolution is overly costly, it may bias the system against smaller firms – whether they are claimants or defendants. Smaller firms may thus innovate less, either because they have difficulty enforcing their patent rights or they are more exposed to infringement accusations from competitors.[66] Enforcement costs may be an especially binding constraint for firms in more resource-constrained low- and middle-income countries, which explains why many of them do not apply for patent rights in the first place.

Promoting patent quality is bound to reinforce more balanced dispute resolution and vice-versa. Quality patents that have undergone rigorous examination are less likely to be challenged in court. Conversely, effective dispute settlement preempts the filing of poor-quality patents, as the prospect of enforcing them is low.

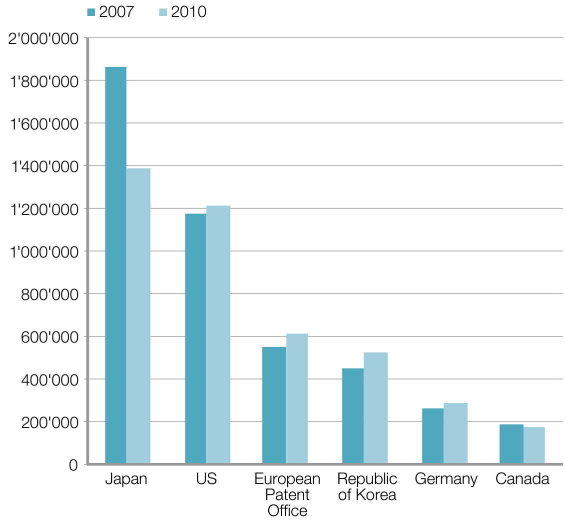
2.3.2

How patenting trends have challenged patent offices

Over the last 15 years, many patent offices have seen a rise in their application backlogs. While there is no unique metric of office backlogs, WIPO estimates that the number of unprocessed applications worldwide stood at 5.17 million in 2010.[67] In absolute terms, the Japan Patent Office (JPO), the United States Patent and Trademark Office (USPTO) and the EPO account for the largest office backlogs (see Figure 2.3, left). However, relative to annual application flows, patenting backlogs are substantial in many other offices, including those in low- and middle-income countries (See WIPO, 2011b).

Figure 2.3: Workload in many patent offices is piling up

Unprocessed patent applications in selected large offices, 2007 and 2010



Source: WIPO Statistics Database, October 2011.

66 A study of IP enforcement in smaller UK firms confirms that the financial costs of litigation deter enforcement. See Greenhalgh and Rogers (2010). See also Lemley (2001) and Lanjouw and Schankerman (2004).

67 This estimate is based on pending applications data from 70 patent offices, which include the top 20 offices except for China, India, and Singapore. Care is required in comparing backlog figures across offices. In some patent offices – notably, the Japanese and German offices – applicants can delay patent examination for several years. The JPO recently revised its statistics on unprocessed patent applications downward.

Many offices have also seen a lengthening of patent pendency times. For example, between 1996 and 2007, average pendency times increased from 21.5 to 32 months at the USPTO and from 24.4 to 45.3 months at the EPO.[68]

Rising office backlogs and lengthening pendency times have coincided with rapid growth in the number of patent applications (see Subsection 1.3.1). However, fast patenting growth is only one factor behind increased office strain. Indeed, some offices have managed to reduce backlogs and shorten pendency times despite rapid patenting growth – mainly by expanding examination capacity.[69]

In addition, in those offices that have experienced growing backlogs and longer pendency times, other factors have played a role, especially an increase in the size of patent applications. At the EPO, for example, average application size jumped from 14 to 30 pages between 1988 and 2005, while the average number of claims per patent increased from 12 to 21.[70] Growing technological complexity appears to be one important driver of larger patent applications.[71] Examining more complex patents takes longer – not least because patent examiners need to learn about new technologies and the corresponding legal rules. Such patents may also require more frequent communication between applicants and examiners, further prolonging examination.

What is the effect of longer pendency times? At least some innovating companies are bound to suffer from long delays in the patenting process. Subsection 2.2.1 discussed evidence that, for some entrepreneurs, the grant of a patent makes a difference in attracting financing from venture capitalists, especially in early financing stages. However, for more established firms, patenting delays may be less problematic and could even be beneficial. Indeed, many patent offices allow applicants to request accelerated examination of patents, but few applicants actually do so.[72]

Some firms – especially in industries with long product life cycles and high uncertainty about market developments – might welcome a longer patenting process to collect more information about an invention's technological and commercial potential. Applicants can thus avoid paying grant and renewal fee payments in case they decide to drop the application. In addition, longer examination enables applicants to submit new or amended patent claims based on what they learn while developing an invention.

Even if some applicants gain, longer pendency times are problematic for society as a whole, because they prolong the period of uncertainty about which technologies may in the future be proprietary. In addition, longer examination may invite anticompetitive and rent-seeking behavior. In particular, it creates incentives to file low-quality patents specifically intended to create uncertainty among competitors. It may also encourage applicants to insert claims that map onto the uses of technology they see developing in the marketplace.

68 For the JPO, data are only available starting in 2000, but the trend is the same: pendency times increased from 26.9 months in 2000 to 32.4 months in 2007. As with backlog figures, care is required in directly comparing pendency times across offices. See WIPO (2011a).
69 See WIPO (2011a).
70 See van Zeebroeck *et al.* (2008) and van Zeebroeck *et al.* (2009).
71 See Lanjouw and Schankerman (2001) and van Zeebroeck *et al.* (2008).
72 To some extent, high costs and procedural requirements may discourage the use of accelerated examination.

Realizing their possible harmful effects, many patent offices have sought to reduce pendency times. However, this is not always easy. Offices only partly control the length of examination. Applicants decide how to draft applications and how they communicate with offices.[73] To the extent that they benefit from longer examination – whatever the underlying reasons may be – applicants may seek to strategically delay the process; for example, they may introduce ambiguities in patent claims that prompt future examiner enquiries.[74]

In addition, confronted with large, growing backlogs, patent offices face the risk that quicker examination may compromise patent quality. Numerous commentators have argued that the pressure created by rising workloads has caused deteriorating patent quality in some offices, especially in the US.[75] Indeed, improving the quality of patents granted was a key objective behind the patent reform legislation recently enacted in the US.[76] More generally, given the difficulty of objectively measuring patent quality, it is hard to empirically assess how systemic quality problems are and how quality differs across offices. Finally, how backlogs affect patent quality is not only important in high-income countries. As pointed out above, many offices in low- and middle-income countries have accumulated substantial backlogs in recent years. They also typically have fewer resources to support thorough examination, increasing the risk of granting low-quality patents.[77]

73 For example, van Zeebroeck *et al.* (2008) argue that countries that follow US drafting styles tend to have more voluminous patent applications compared to filings at the EPO.

74 Mejer and van Pottelsberghe de la Potterie (2011) conjecture that applicants who delay the patenting process are the root cause of backlogs at the EPO.

75 See, for example, Jaffe and Lerner (2004) and Guellec and van Pottelsberghe de la Potterie (2007).

76 See the statement of USPTO Director David Kappos before the US House of Representatives, available at *www.uspto.gov/news/speeches/2011/kappos_house_testimony.jsp*.

77 Sampat (2010) discusses how resource constraints might have affected pharmaceutical patents granted in India.

78 Using a panel dataset, Rassenfosse and van Pottelsberghe de la Potterie (2011) estimate a demand elasticity for patents of -0.3, implying that a 10 percent increase in the patenting fee leads to a 3 percent fall in patent volumes.

2.3.3

The choices patent institutions face

The choices facing patent institutions determine how the system promotes the principles of patent quality and balanced dispute resolution. What may seem like a minor change in procedural rules or a management response to operational demands may have far-reaching consequences for patent system use. Relevant institutional choices are often specific to countries' legal systems and their level of development. However, a number of common choices exist. This final subsection points to some of the most important ones.

First, to ensure quality examination, patent offices need to be properly resourced. This raises the question of how their operations should be funded. The two prevailing models are: financing them out of general government spending; or through the fees they collect. Difficult trade-offs exist. Fee-based financing can establish incentives for operational efficiency and insulates patent offices from the ups and downs of public budgets. However, patent offices that seek to maximize fee income may adjust their operations in a way that conflicts with society's best interest. Above all, quickly processing patent applications may maximize fee revenue, but that might come at the expense of patent quality. In fee-financed offices, it is therefore important to establish complementary performance incentives that promote patent quality.

A closely related second institutional choice concerns the level and structure of patenting fees. While fees charged by offices are only one – and usually a small – component of the legal costs applicants face, studies have clearly shown that higher fees lead to lower patenting activity.[78] Fees are thus an important regulatory instrument. As a rule of thumb, fees should be sufficiently low to ensure equitable access to the system, but not so low as to encourage speculative applications.

One dilemma in establishing a fee policy is that it can only serve one purpose. In particular, a set of fees that ensures office cost recovery may not coincide with society's best interest – and vice-versa. For example, cost recovery would call for high filing fees to support labor-intensive examination work and low fees for renewing patents that involve very little work for offices. However, low renewal fees may not be in society's best interest, as they prolong protection for patents inventors no longer highly value.[79] In fact, for the latter reason, economists have argued for an escalating renewal fee structure.[80]

A third important institutional choice concerns the interests of third parties in the patenting process. Third parties may provide useful information on relevant prior art that bears on the patentability of an invention. In addition, if the grant of a patent affects them, they may want to challenge its validity before it leaves the patent office, preempting more expensive court litigation down the road. Many patent offices have therefore adopted mechanisms allowing for third party information submission and patent opposition (see Box 2.5 for one example).[81] Such mechanisms can usefully promote patent quality.[82] However, building on the principle of balanced dispute resolution, they should be designed in such a way that they open the door to legitimate third party interests, but minimize the risk of bad faith challenges that unduly burden patent applicants.

Box 2.5: Crowd-sourcing patent examination

No matter how qualified and dedicated patent examiners are, they may miss out on important prior art. For example, there are instances where the state of the art progresses at a faster pace than examiners can match. In addition, examiners may only have incomplete access to non-patented prior art, especially in new areas of patenting. In such cases, it is useful to enlist the help of the public to identify information related to inventions under review. A new crowd-sourcing initiative – called Peer-to-Patent – makes use of social networking software to assist patent offices in their examination work.

The original Peer-to-Patent initiative – launched by the New York Law School and the USPTO as a pilot program in June 2007 – focused on using members of the open source community to help identify relevant prior art in the areas of computer architecture, software and information security. Community members were able to review and rate documents they considered important in determining the patentability of particular inventions. Patent examiners could later use these documents in examination if they were deemed relevant. A review of the pilot program was positive, and the project has now been extended to cover subject areas beyond the initial three technology areas.

Given the success of the pilot program in the US, patent offices in Australia, Japan, the Republic of Korea and the United Kingdom (UK) have each launched similar initiatives to assess the feasibility of this mechanism in their countries.

Source: Wong and Kreps (2009).

Strategic use of ICTs by patent offices is an increasingly important fourth institutional choice. Most patent office operations consist of the processing of information. Modern ICTs can not only improve operational efficiency, but also promote patent quality. This is especially the case for prior art searches. Digital access to patent and non-patent literature, combined with sophisticated search algorithms – and, increasingly, automated translation – can reduce the risk that examiners might miss important prior art.[83] In addition, the timely provision of patent information in digital form enlarges the potential for knowledge spillovers, as discussed in Subsection 2.2.4.

79 Gans *et al.* (2004) provide a theoretical exposition of this argument.

80 See Schankerman and Pakes (1986), Lanjouw, Pakes and Putnam (1998), Scotchmer (1999) and Cornelli and Schankerman (1999).

81 See WIPO (2009) for an overview of the patent opposition system and a summary of some countries' laws and practices. Rotstein and Dent (2009) and Graham *et al.* (2003) compare the third party opposition systems of the EPO, USPTO and JPO.

82 Hall *et al.* (2004), for example, discuss the quality benefits of post-grant opposition.

83 Michels and Bertels (2001) show significant differences in the results of prior art searches across the major offices, partly attributable to language barriers.

A fifth important institutional choice concerns international cooperation. As noted in Subsection 1.3.1, around one-half of the increase in patent filings worldwide from 1995 to 2007 was due to subsequent patent filings, most of which represented international filings. In practice, this means that national patent offices increasingly look at the same patents. International cooperation – as already practiced through the Patent Cooperation Treaty (PCT) – can help in reducing duplication of work. In addition, combining the resources of more than one office can help promote patent quality.

International cooperation can take place at different levels of ambition – from the simple exchange of information to the recognition of foreign grant decisions. In between, there are many options. Deciding on the appropriate level of cooperation involves many considerations – including how offices trust the work of their foreign counterparts, how compatible domestic patenting standards are with those abroad, how cooperation affects filing behavior and office workload, and the learning benefits that may be lost by not examining patents domestically.

Finally, one of the most challenging choices is the design of enforcement institutions. Litigation is invariably a costly activity – for litigants and courts. Balanced and timely dispute resolution requires substantial resources and skilled judges. Specialized patent courts can improve efficiency and promote consistent rulings, but they may not be an option in smaller and less developed economies. Institutional innovation that provides for alternative dispute resolution short of outright litigation may be helpful in preempting costly litigation. For example, some patent offices offer administrative dispute resolution, mediation or advice on questions of patent validity and infringement – including some offices in middle-income countries.[84] Patent opposition – as outlined above – is another form of early dispute resolution.

There are other important considerations in designing enforcement institutions – for example, whether judges should decide on patent infringement and validity at the same time or in separate cases, and how courts should be financed. No comparative research exists that offers general guidance on which approaches work best. A better understanding of enforcement institutions and their effects on patenting behavior are, arguably, priority areas for future research.

84 The UK Intellectual Property Office offers a patent validity search service that provides firms with information on whether a patent granted is vulnerable to legal challenge see *www.ipo.gov.uk/types/patent/p-other/p-infringe/p-validity.htm.*

2.4

Conclusions and directions for future research

Understanding how IP protection affects innovative behavior has been a fertile field in economic research. Important insights gained long ago arguably still shape how economists view the IP system today. Above all, compared to other innovation policies, IP protection stands out in that it mobilizes decentralized market forces to guide R&D investment. This works especially well where private motivation to innovate aligns with society's technological needs, where solutions to technological problems are within sight, and where firms can finance upfront R&D investment.

However, difficult trade-offs exist in designing IP rights, not least because IP protection has multifaceted effects on innovative behavior and market competition. As technologies advance and business models shift, optimally balancing these trade-offs represents a continual high-stakes challenge.

In more recent history, economists have refined their view of the IP system – partly as a result of new research and partly due to real world developments. The patent system has received special attention, in at least two ways:

- The build-up of strategic patenting portfolios in complex technologies has raised concerns about patent rights slowing or even forestalling cumulative innovation processes. Entrepreneurs facing dense webs of overlapping patent rights – or patent thickets – may forgo research activities or shelve plans for commercializing promising technologies.

- Patents play an important role in modern technology markets. They enable firms to specialize, allowing them to be more innovative and efficient at the same time. In addition, they allow firms to flexibly control which knowledge to guard and which to share so as to maximize knowledge spillovers – a key element of open innovation strategies. Finally, the widespread availability of patent information has created vast opportunities for technological learning and catch-up by less developed economies.

The effectiveness of the patent system in promoting innovation is critically dependent on how the rules set by laws are implemented in practice. Patent institutions have moved to the center stage of the modern innovation system. They perform the essential tasks of ensuring the quality of patents granted and providing balanced dispute resolution. Unprecedented levels of patenting in many high- and middle-income countries have put these institutions under considerable pressure. The choices they make have far-reaching consequences on incentives to innovate.

Areas for future research

Even though economic research has come a long way since the galvanizing work by Kenneth Arrow some 50 years ago, there are many questions for which future research could offer better guidance to policymakers:

- Most academic studies have focused on high-income countries. While they can in many ways inform policymakers throughout the world, the varying innovative and absorptive capacity of middle- and low-income countries suggests that IP protection operates differently in these economies. A better understanding of the conditions under which different IP forms can incentivize R&D and promote the formation of technology markets is therefore crucial.

- Only limited guidance is available on how the different patent-based knowledge sharing activities – especially those associated with more recent open innovation models – affect knowledge spillovers and innovation outcomes. A related question concerns the extent to which greater openness in the innovation process has created greater opportunities for technological catch-up by firms in less developed economies.

- Further research is needed on how the choices of patent institutions affect innovation incentives, especially in the area of rights enforcement.

REFERENCES

Abbott, F.M., Cottier, T. & Gurry, F. (2007). *International Intellectual Property in an Integrated World Economy.* Nashua: The Book Cellar, LLC.

Aghion, P., Bloom, N., Blundell, R., Griffith, R. & Howitt, P. (2005). Competition and Innovation: An Inverted-U Relationship. *Quarterly Journal of Economics, 120(2),* 701-728.

Alchian, A.A. & Demsetz, H. (1972). Production, Information Costs, and Economic Organization. *The American Economic Review, 62*(5), 777-795.

Arora, A. & Ceccagnoli, M. (2006). Patent Protection, Complementary Assets, and Firms' Incentives for Technology Licensing. *Management Science, 52*(2), 293-308.

Arora, A., Ceccagnoli, M. & Cohen, W.M. (2008). R&D and the Patent Premium. *International Journal of Industrial Organization, 26*(5), 1153-1179.

Arora, A., Fosfuri, A. & Gambardella, A. (2001a). Markets for Technology and Their Implications for Corporate Strategy. *Industrial and Corporate Change, 10*(2), 419-451.

Arora, A., Fosfuri, A. & Gambardella, A. (2001b). *Markets for Technology: Economics of Innovation and Corporate Strategy.* Cambridge, MA: MIT Press.

Arora, A. & Gambardella, A. (2010). Ideas for Rent: An Overview of Markets for Technology. *Industrial and Corporate Change, 19*(3), 775-803.

Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention. In R.R. Nelson (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors.* Princeton, NJ: Princeton University Press, 609-626.

Arrow, K. (1971). *Essays in the Theory of Risk-Bearing.* Chicago: Markham Publishing Company.

Benavente, J.M. (2011). The Economics of IP in the Context of a Middle Income Country. Unpublished manuscript. Geneva: World Intellectual Property Organization.

Bresnahan, T.F. & Gambardella, A. (1998). The Division of Inventive Labor and the Extent of the Market. In E. Helpman (Ed.), *General Purpose Technologies and Economic Growth.* Cambridge, MA: MIT Press, 253-282.

Brouwer, E. & Kleinknecht, A. (1999). Innovative Output, and a Firm's Propensity to Patent.: An Exploration of CIS Micro Data. *Research Policy, 28*(6), 615-624.

Choi, J.P. (1998). Patent Litigation as an Information-Transmission Mechanism. *The American Economic Review, 88*(5), 1249-1263.

Coase, R.H. (1937). The Nature of the Firm. *Economica, 4*(16), 386-405.

Cockburn, I.M. & MacGarvie, M.J. (2009). Patents, Thickets and the Financing of Early-stage Firms: Evidence from the Software Industry. *Journal of Economics and Management Strategy, 18*(3), 729-773.

Cockburn, I.M., MacGarvie, M.J. & Müller, E. (2010). Patent Thickets, Licensing and Innovative Performance. *Industrial and Corporate Change, 19*(3), 899-925.

Cohen, W.M., Goto, A., Nagata, A., Nelson, R.R. & Walsh, J.P. (2002). R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States. *Research Policy, 31*(8-9), 1349-1367.

Cohen, W.M. & Levinthal, D.A. (1989). Innovation and Learning: The Two Faces of R&D. *The Economic Journal, 99*, 569-596.

Cohen, W.M. & Levinthal, D.A. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, Special Issue: Technology, Organizations, and Innovation, *35*(1), 128-152.

Cohen, W.M., Nelson, R.R. & Walsh, J.P. (2000). Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not). *National Bureau of Economic Research Working Paper, No. 7552.*

Cornelli, F. & Schankerman, M. (1999). Patent Renewals and R&D Incentives. *The RAND Journal of Economics, 30*(2), 197-213.

David, P.A. (1993). *Knowledge, Property and the System Dynamics of Technological Change.* Paper presented at the Proceedings of the World Bank Annual Conference on Development Economics, 1992.

Dushnitski, G. & Klueter, T. (2011). Is There an eBay for Ideas? Insights from Online Knowledge Marketplaces. *European Management Review, 8*(1), 17-32.

Eisenberg, R.S. (1996). Intellectual Property Issues in Genomics. *Trends in Biotechnology, 14*(8), 302-307.

Fink, C., Smarzynska Javorcik, B. & Spatareanu, M. (2005). Income-Related Biases in International Trade: What Do Trademark Registration Data Tell Us? *Review of World Economics, 141*(1), 79-103.

Gambardella, A. & Giarratana, M.S. (2011). General Technological Capabilities, Product Market Fragmentation, and Markets for Technology: Evidence from the Software Security Industry. *Bocconi University Working Paper.*

Gambardella, A., Harhoff, D. & Nagaoka, S. (2011). *The Social Value of Patent Disclosure.* Unpublished manuscript. Munich: Ludwig-Maximilians Universität.

Gambardella, A. & McGahan, A.M. (2010). Business-model Innovation: General Purpose Technologies and Their Implications for Industry Structure. *Long Range Planning, 43*(2-3), 262-271.

Gans, J.S., King, S.P. & Lampe, R. (2004). Patent Renewal Fees and Self-funding Patent Offices. *Topics in Theoretical Economics, 4*(1).

Geradin, D., Layne-Farrar, A. & Padilla, A.J. (2011). Elves or Trolls? The Role of Nonpracticing Patent Owners in the Innovation Economy. *Industrial and Corporate Change*, forthcoming.

Gilbert, R. & Shapiro, C. (1990). Optimal Patent Length and Breadth. *The RAND Journal of Economics*, 21(1), 106-112.

Gilbert, R.J. & Newbery, D. (1982). Preemptive Patenting and the Persistence of Monopoly. *American Economic Review*, 72, 514-526.

Giuri, P., Mariani, M., Brusoni, S., Crespi, G., Francoz, D., Gambardella *et al.* (2007). Inventors and Invention Processes in Europe: Results from the PatVal-EU Survey. *Research Policy*, 36(8), 1107-1127.

Graham, S., Hall, B., Harhoff, D. & Mowery, D. (2003). Patent Quality Control: A Comparison of U.S. Patent Re-examination and European Patent Oppositions. In W.M. Cohen & S.A. Merrill (Eds.), *Patents in the Knowledge-Based Economy* (Vol. 74-119). Washington, D.C.: National Academy of Sciences, 74-119.

Graham, S. & Sichelman, T. (2008). Why Do Start-ups Patent? *Berkeley Technology Law Journal*, 23(1), 1071-1090.

Graham, S.J.H., Merges, R.P., Samuelson, P. & Sichelman, T. (2009). Entrepreneurs and the Patent System. *Berkeley Technology Law Journal, 24*(4), 1258-1328.

Granstrand, O. (1999). *The Economics and Management of Intellectual Property.* Cheltenham: Edward Elgar Publishing Limited.

Granstrand, O. (2011). *The Economics of IP in the Context of a Shifting Innovation Paradigm.* Unpublished manuscript. Geneva: World Intellectual Property Organization.

Green, J. & Scotchmer, S. (1995). On the Division of Profit in Sequential Innovation. *The RAND Journal of Economics, 26*, 20-33.

Greenberg, G. (2010). *Small Firms, Big Patents? Estimating Patent Value Using Data on Israeli Start-ups Financing Rounds.* Paper presented at the 4th Israeli Strategy Conference.

Greenhalgh, C. & Rogers, M. (2010). *Innovation, Intellectual Property and Economic Growth.* Princeton and Oxford: Princeton University Press.

Guellec, D. & van Pottelsberghe de la Potterie, B. (2007). *The Economics of the European Patent System: IP Policy for Innovation and Competition.* Oxford: Oxford University Press.

Hall, B.H. (2009). *The Use and Value of IP Rights.* Paper presented at the UK IP Ministerial Forum on the Economic Value of Intellectual Property.

Hall, B.H., Graham, S., Harhoff, D. & Mowery, D. (2004). Prospects for Improving U.S. Patent Quality via Postgrant Opposition. In A.B. Jaffe, J. Lerner & S. Stern (Eds.), *Innovation Policy and the Economy* (Vol. 4). Cambridge, MA: MIT Press, 115-144.

Hall, B.H. & Helmers, C. (2011). Innovation and Diffusion of Clean/Green Technology: Can Patent Commons Help? *National Bureau of Economic Research Working Paper Series, No. w16920.*

Hall, B.H. & Lerner, J. (2010). The Financing of R&D and Innovation. In B.H. Hall & N. Rosenberg (Eds.), *Handbook of the Economics of Innovation.* Amsterdam: Elsevier-North Holland.

Hall, B.H., & Ziedonis, R.H. (2001). The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995. *The RAND Journal of Economics, 32*(1), 101-128.

Harabi, N. (1995). Appropriability of Technical Innovations: An Empirical Analysis. *Research Policy, 24*(6), 981-992.

Harhoff, D. (2006). Patent Quantity and Quality: Trends and Policy Implications. In B. Kahin & D. Foray (Eds.), *Advancing Knowledge and the Knowledge Economy.* Cambridge and London: MIT Press, 331-350.

Harhoff, D. (2009). The Role of Patents and Licenses in Securing External Finance for Innovation. *European Investment Bank Papers, 14*(2), 74-96.

Harhoff, D., Hall, B.H., von Graevenitz, G., Hoisl, K. & Wagner, S. (2007). The Strategic Use of Patents and Its Implications for Enterprise and Competition Policies. *Report Commissioned by European Commission* (Tender ENTR/05/82). Brussels: European Commission.

Heller, M. & Eisenberg, R. (1998). Can Patents Deter Innovation? The Anticommons in Biomedical Research. *Science, 280*, 698-701.

Hsu, D. & Ziedonis, R.H. (2008). *Patents as Quality Signals for Entrepreneurial Ventures.* Unpublished manuscript.

Jaffe, A.B. (2000). The US Patent System in Transition: Policy Innovation and the Innovation Process. *Research Policy, 29*(4-5), 531-557.

Jaffe, A.B. & Lerner, J. (2004). *Innovation and Its Discontents: How Our Broken Patent System is Endangering Innovation and Progress, and What to Do about It.* Princeton: Princeton University Press.

Kanwar, S. & Evenson, R.E. (2003). Does Intellectual Property Protection Spur Technical Change? *Oxford Economic Papers, 55*, 235-264.

Kim, L. (1997). *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* Boston: Harvard Business Press.

Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy, 99*(3), 483-499.

Kyle, M. & McGahan, A.M. (2011). Investments in Pharmaceuticals before and after TRIPS. *Review of Economics and Statistics, forthcoming.*

Lall, S. (2003). Indicators of the Relative Importance of IPRs in Developing Countries. *Research Policy, 32*(9), 1657-1680.

Lanjouw, J.O., Pakes, A. & Putnam, J. (1998). How to Count Patents and Value Intellectual Property: The Uses of Patent Renewal and Application Data. *The Journal of Industrial Economics, 46*(4), 405-432.

Lanjouw, J.O. & Schankerman, M. (2001). Characteristics of Patent Litigation: A Window on Competition. *The RAND Journal of Economics, 32*(1), 129-151.

Lanjouw, J.O. & Schankerman, M. (2004). Protecting Intellectual Property Rights: Are Small Firms Handicapped? *The Journal of Law and Economics, 47*(1), 45-74.

Lee, K. (2010). *Intellectual Property Rights and Innovation in Economic Development in Korea.* Paper presented at the KDI International Conference on Intellectual Property for Economic Development: Issues and Policy Implications.

Lee, K. & Kim, Y.-K. (2010). IPR and Technological Catch-up in Korea. In H. Odagiri, A. Goto, A. Sunami & R.R. Nelson (Eds.), *Intellectual Property Rights, Development, and Catch Up: An International Comparative Study.* Oxford: Oxford University Press.

Lemley, M.A. (2000). Reconceiving Patents in the Age of Venture Capital. *Journal of Small and Emerging Business Law, 4*(1), 137-148.

Lemley, M.A. (2001). Rational Ignorance at the Patent Office. *Northwestern University Law Review, 95*, 1495.

Lemley, M.A. & Burk, D.L. (2003). *Policy Levers in Patent Law. Virginia Law Review, 89,* 1575.

Lemley, M.A. & Shapiro, C. (2005). Probabilistic Patents. *Journal of Economic Perspectives, 19*(2), 75-98.

Lemley, M.A. & Shapiro, C. (2007). Patent Holdup and Royalty Stacking. *Texas Law Review, 85*.

Lerner, J. (2010). The Litigation of Financial Innovations. *Journal of Law and Economics, 53*(4), 807-831.

Lerner, J. & Tirole, J. (2005). The Economics of Technology Sharing: Open Source and Beyond. *The Journal of Economic Perspectives, 19*(2), 99-120.

Lerner, J. & Zhu, F. (2007). What is the Impact of Software Patent Shift? Evidence from *Lotus v. Borland. International Journal of Industrial Organization, 25*(3), 511-529.

Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Gilbert, R. & Griliches, Z. (1987). Appropriating the Returns from Industrial Research and Development. *Brookings Papers on Economic Activity, 1987*(3), 783-831.

Love, J. & Hubbard, T. (2009). Prizes for Innovation of New Medicines and Vaccines. *Annals of Health Law, 18*(2), 155-186.

Mansfield, E. (1986). Patents and Innovation: *An Empirical Study. Management Science, 32*(2), 173-181.

Mejer, M. & van Pottelsberghe de la Potterie, B. (2011). Patent Backlogs at UPSTO and EPO: Systemic Failure vs Deliberate Delays. *World Patent Information, 33*(2), 122-127.

Michel, J. & Bettels, B. (2001). Patent Citation Analysis – A Closer Look at the Basic Input Data from Patent Search Reports. *Scientometrics, 21*(1), 185-201.

Moser, P. (2005). How Do Patent Laws Influence Innovation? Evidence from Nineteenth-Century World's Fairs. *American Economic Review, 95*(4), 1214-1236.

Murray, F. & Stern, S. (2006). When Ideas Are Not Free: The Impact of Patents on Scientific Research. *Innovation Policy and the Economy, 7,* 33–69.

Murray, F. & Stern, S. (2007). Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge?: An Empirical Test of the Anti-commons Hypothesis. *Journal of Economic Behavior & Organization, 63*(4), 648-687.

Nagaoka, S. (2011). Assessing the Basic Roles of the Patent System in Incentivizing Innovation: Some Evidence from Inventor Surveys in Japan and in the US. Unpublished manuscript. Geneva: World Intellectual Property Organization.

Nagaoka, S. & Walsh, J. (2008). The Objectives, the Process and the Performance of R&D Projects in the US and Japan: Major Findings from the RIETI-Georgia Tech Inventor Survey. *RIETI Discussion Paper.*

Nelson, R.R. (Ed.) (1993). *National Innovation Systems: A Comparative Analysis.* New York: Oxford University Press.

Nelson, R.R. & Winter, S.G. (1982). *An Evolutionary Theory of Economic Change.* Cambridge, Massachusetts and London: Belknap Press of Harvard University Press.

Nicholson, C.V. (2011). Apple and Microsoft Beat Google for Nortel Patents. *The New York Times.* Retrieved from *http://dealbook.nytimes.com/2011/07/01/apple-and-microsoft-beat-google-for-nortel-patents/*

Noel, M. & Schankerman, M. (2006) Strategic Patenting and Software Innovation. Vol. 740. *Centre for Economic Performance Discussion Paper.* London: London School of Economics and Political Science.

Nordhaus, W. (1969). Invention, Growth, and Welfare: *A Theoretical Treatment of Technological Change.* Cambridge: MIT Press.

O'Donoghue, T., Scotchmer, S. & Thisse, J.-F. (1998). Patent Breadth, Patent Life, and the Pace of Technological Progress. *Journal of Economics & Management Strategy, 7*(1), 1-32.

Pakes, A. (1986). Patents as Options: Some Estimates of the Value of Holding European Patent Stocks. *Econometrica, 54*(4), 755-784.

Park, G.S. Hwang, S.D. (2010). The Rise of the NPE. *Managing Intellectual Property.* Retrieved from *www.managingip.com/Article/2740039/The-rise-of-the-NPE.html*

Park, W. & Ginarte, J.C. (1997). Intellectual Property Rights and Economic Growth. *Contemporary Economic Policy, 15*, 51-61.

Qian, Y. (2007). Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment? A Cross-country Analysis of Pharmaceutical Patent Protection, 1978-2002. *Review of Economics and Statistics, 89*(3).

de Rassenfosse, G. & van Pottelsberghe de la Potterie, B. (2011). On the Price Elasticity of Demand for Patents. *Oxford Bulletin of Economics and Statistics,* forthcoming.

Rotstein, F. & Dent, C. (2009). Third-Party Patent Challenges in Europe, the United States and Australia: A Comparative Analysis. *The Journal of World Intellectual Property, 12*(5), 467-500.

Sakakibara, M. & Branstetter, L. (2001). Do Stronger Patents Induce More Innovation? Evidence from 1988 Japanese Patent Law Reforms. *The RAND Journal of Economics, 32*(1), 77-100.

Sampat, B.N. (2010). *Institutional Innovation or Institutional Imitation? The Impacts of TRIPS on India's Patent Law and Practice.* Paper presented at the WIPO Seminar Series on "The Economics of Intellectual Property" on December 13, 2010.

Schankerman, M. (1998). How Valuable is Patent Protection? Estimates by Technology Field. *The RAND Journal of Economics, 29*(1), 77-107.

Schankerman, M. & Pakes, A. (1986). Estimates of the Value of Patent Rights in European Countries during the Post-1950 Period. The Economic Journal, 96(384), 1052-1076.

Schumpeter, J. (1937). Preface to to the Japanese Edition. *Theorie der Wirtschaftlichen Entwicklung.* Reprinted in R.V. Clemence (Ed.), *Essays on Entrepreneurs, Innovations, Business Cycles and the Evolution of Capitalism.* New Brunswick, N.J.: Transaction Publishers (1989), 165-168.

Schumpeter, J. (1943). *Capitalism, Socialism and Democracy.* New York: Harper.

Scotchmer, S. (1991). Standing on the Shoulders of Giants: Cumulative Research and the Patent Law. *The Journal of Economic Perspectives, 5*(1), 29-41.

Scotchmer, S. (1996). Protecting Early Innovators: Should Second-generation Products be Patentable? *The RAND Journal of Economics, 27*(2), 322-331.

Scotchmer, S. (1999). On the Optimality of the Patent Renewal System. *The RAND Journal of Economics, 30,* 181-196.

Scotchmer, S. (2004). *Innovation and Incentives.* Cambridge: MIT Press.

Shapiro, C. (2001). Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting. *Innovation Policy and the Economy, 1*(119-150).

Sichelman, T. & Graham, S. (2010). Patenting by Entrepreneurs: An Empirical Study. *Michigan Telecommunications and Technology Law Review, 17,* 111-180.

Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations.* London: W. Strahan and T. Cadell.

Sussex, J., Towse, A. & Devlin, N. (2011). Operationalising Value Based Pricing of Medicines: A Taxonomy of Approaches. *OHE Research Paper.*

Suthersanen, U. (2006). *Utility Models and Innovation in Developing Countries.* Geneva: ICTSD-UNCTAD.

Teece, D.J. (1986). Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy, 15*(6), 285-305.

Teece, D.J. (1988). Technological Change and the Nature of the Firm. In G. Dosi, C. Freeman, R.R. Nelson, G. Silverberg & L. Soete (Eds.), *Technical Change and Economic Theory.* London: Pinter, 256-281.

Thursby, J. & Thursby, M. (2006). Where is the New Science in Corporate R&D? *Science, 314*(5805), 1547-1548.

Thursby, J. & Thursby, M. (2011). Protection of Intellectual Property and R&D Location. Unpublished manuscript. Geneva: World Intellectual Property Organization.

Thursby, M. & Thursby, J. (2006) Here or There? A Survey on the Factors in Multinational R&D Location. *Report to the Government-University-Industry Research Roundtable.* Washington, D.C.: National Academies Press.

Tullock, G. (Ed.) (1987) New Palgrave Dictionary of Economics (Vol. 4).

van Zeebroeck, N., Stevnsborg, N., van Pottelsberghe de la Potterie, B., Guellec, D. & Archontopolos, E. (2008). Patent Inflation in Europe. *World Patent Information, 30,* 43-52.

van Zeebroeck, N., van Pottelsberghe de la Potterie, B. & Guellec, D. (2009). Claiming More: the Increased Voluminosity of Patent Applications and its Determinants. *Research Policy, 38*(6), 1006-1020.

Verbeure, B., van Zimmeren, E., Matthijs, G. & Van Overwalle, G. (2006). Patent Pools and Diagnostic Testing. *Trends in Biotechnology, 24*(3), 115-120.

Williamson, O.E. (1981). The Modern Corporation: Origins, Evolution, Attributes. *Journal of Economic Literature, 19*(4), 1537-1568.

WIPO (2009). Opposition Systems. SCP/14/5. Document prepared for the Standing Committee on the Law of Patents (SCP), Fourteenth Session, January 25 to 29, 2010. Geneva: World Intellectual Property Organization.

WIPO (2011a). The Surge in Worldwide Patent Applications. *PCT/WG/4/4.* Study prepared for the Patent Cooperation Treaty (PCT) Working Group. Geneva: World Intellectual Property Organization.

WIPO (2011b, forthcoming). *World Intellectual Property Indicators.* Geneva: World Intellectual Property Organization.

Wong, C. & Kreps, J. (2009). Collaborative Approach: Peer-to-Patent and the Open Source Movement. *International Free and Open Source Software Law Review, 1*(1), 15-26.

World Bank. (2001). Intellectual Property: Balancing Incentives with Competitive Access. *Global Economic Prospects.* Washington, D.C.: World Bank, 129-150.

Yu, T.F.-L. (1998). Adaptive Entrepreneurship and the Economic Development of Hong Kong. *World Development, 26*(5), 897-911.

Zuñiga, M.P. & Guellec, D. (2009). Who Licenses out Patents and Why?: Lessons from a Business Survey. *OECD Science, Technology and Industry Working Papers 2009/5.*

CHAPTER 3 BALANCING COLLABORATION AND COMPETITION

Greater collaboration between firms in the innovation process is seen as one important element of the changing face of innovation. Survey evidence indicates that the great majority of research and development (R&D)-intensive firms pursue some form of collaboration. Joining forces with others is also at the heart of modern open innovation approaches – even if the significance of such approaches is still uncertain (see Chapter 1).

Private collaboration has the potential to improve societal welfare by most effectively utilizing the core competencies of individual firms. However, collaboration also creates a tension on two levels:

- Tension due to the competing interests of collaborators. Firms must weigh the efficiency gains from sharing efforts and knowledge against the risks that partners may act opportunistically.
- Tension between producers of intellectual property (IP) and the public good. Policymakers are eager to encourage the efficient introduction of new technologies, favoring cooperation; however, they must guard against harmful anticompetitive practices.

Drawing on the economic literature, this chapter explores these tensions and their implications for business decisions and policymaking. It first focuses on collaboration between firms in the production of IP (Section 3.1) and in the commercialization of IP (Section 3.2). Then, the chapter reviews how anticompetitive practices are addressed in the competition policy frameworks of certain jurisdictions (Section 3.3). The concluding remarks summarize some of the key messages emerging from the economic literature and point to areas where more research could usefully guide policymakers (Section 3.4).

3.1

Collaborating to generate new IP

Firms may collaborate at different stages in the innovation process (see Subsection 1.2.5). Conceptually, it is helpful to distinguish between collaboration in producing IP and collaboration in commercializing IP. This section focuses on the former and considers the following two forms of formal R&D collaboration:

- Contractual partnerships – These often take place in the context of a defined project and may involve the sharing of personnel and costs such as laboratories, offices or equipment. These arrangements are usually of a smaller scale and finite time span. Given their project-specific nature, collaboration objectives are usually relatively specific. For generating new IP, this is by far the most common mode of collaboration.
- Equity-based joint ventures – These involve two or more parent organizations creating and funding a third entity. Companies may establish such collaboration agreements specifically to make the entity more independent in governance. This form of collaboration represents a larger commitment and requires higher coordination costs. Although it makes the option of changing partners far less flexible, the entity’s actual goals can be more flexibly defined at the organizational rather than the project level.

These two forms of formal collaboration – generally referred to as R&D alliances – do not always result in new IP. But frequently they do and provisions setting out who owns joint research output and how it is shared are often a central element of collaboration agreements.

Following a review of the available data on these forms of collaboration, the discussion explores what motivates firms to collaborate and the complications that arise in joint R&D undertakings. It also briefly reviews the phenomenon of open source software, which departs in important ways from more traditional collaboration approaches.

3.1.1

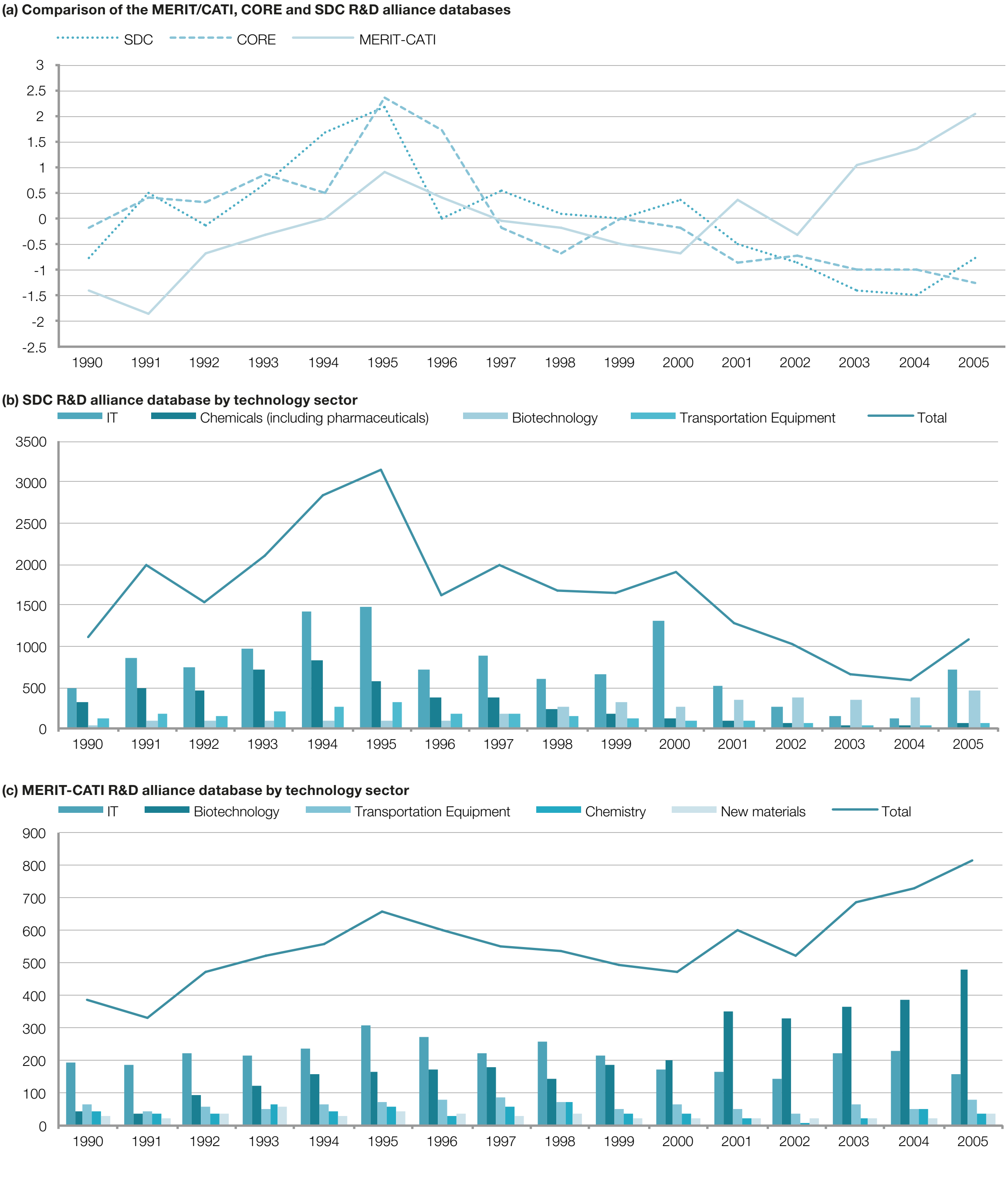
What the available data say about formal R&D collaboration

There is no perfect way to trace contractual R&D partnerships and joint ventures. Aside from a few exceptions, firms do not need to officially report information on their collaborative arrangements. Company annual reports may offer a window onto their collaborative activity, but the information available is typically incomplete and limited to larger firms.

Several non-official databases exist that track announcements of new R&D alliances. Figure 3.1 depicts the trend in new agreements over the 1990-2005 period for different industries, as suggested by three such databases. Two empirical patterns stand out. First, the formation of R&D alliances appears to have peaked in the mid-1990s. Second, the information and communications technology (ICT) industry accounts for the greatest number of agreements for most years, although one data source suggests that the biotechnology industry emerged as the top collaborating industry in the early 2000s. In addition to these industries, the chemical industry also exhibits substantial numbers of collaborative agreements across all three sources.

Figure 3.1: Did R&D alliances peak in the mid-1990s?

Number of R&D alliances (standardized), 1990-2005



Notes: Following Schilling (2009), panel (a) standardizes R&D alliance counts to allow for easier comparisons between the three different databases. As explained in the Data Annex to this chapter, the data collection methodologies of the three different databases differs in important ways. For easier presentation, panel (b) scales down the total count of R&D alliances by a factor of two. In panels (b) and (c), the technology sectors for the SDC and MERIT-CATI databases have been harmonized with a view to improve comparability.

Source: Schilling (2009).

Notwithstanding these similarities, several empirical patterns differ markedly across the three data sources for which there is no obvious explanation. In addition, relying on announcements of new R&D alliances to trace collaborative behavior introduces several biases that may lead to a distorted picture of actual collaboration (see Box 3.1). Another problem of simple alliance counts is that every agreement receives the same weight; in practice, the scope and underlying commercial value of alliances vary substantially. The above empirical insights thus need to be treated with caution.

Box 3.1: Challenges in collecting consistent and comparable data on collaborative agreements

While new open innovation approaches have highlighted the importance of collaboration, it is not a new phenomenon (Chapter 1). Indeed, it is difficult to conclude from the available data that there has been a continuous rise in collaborative agreements over the last decades. However, measurement challenges abound.

In principle, three different types of data could offer empirical insights into collaborative behavior: counts of R&D alliances, innovation surveys and co-patenting behavior. Unfortunately, none of these captures collaborative behavior perfectly, and data collection methods often introduce biases that may even lead to a misleading picture of such behavior.

R&D alliance counts are the most direct way of measuring private collaboration. The available collections – such as the SDC Platinum and MERIT/CATI databases – use a variety of sources to trace R&D alliances, including company annual reports and media announcements (see the Data Annex to this chapter). They invariably miss out on collaboration that is not announced or that does not receive media coverage. In addition, they predominantly cover English-language publications, thus introducing an important geographical bias. Schilling (2009) further discusses the reliability of these data collections.

Innovation surveys offer, in principle, a more rigorous approach to measurement. For example, European Community innovation surveys have collected some information on collaborative behavior and provide important insights into how collaboration varies depending on firm size (see also Subsection 1.3.3). However, innovation survey data often do not distinguish between formal and informal forms of collaborating; in addition, they cannot be easily compared across countries and over time.

Finally, co-patenting data offer an indirect way of capturing collaborative R&D activity between firms. The bibliographical data published in patent documents offer, in principle, rich information on jointly owned inventions. However, not all contractual R&D partnerships and joint ventures may result in subsequent patenting, and co-patenting may not be linked to any formal R&D collaboration. Indeed, the relationship between formal collaboration and subsequent patenting is likely to differ significantly across industries and countries.

A more indirect way of capturing R&D collaboration is to look at co-patenting behavior. Many joint R&D undertakings will result in subsequent patenting, and patent databases can help to identify those patents that have two or more firms as applicants. An analysis of patent filings at the United States Patent and Trademark Office (USPTO) during the years 1989-1998 shows that co-patenting was most frequent in the chemical, ICT and instrumentation industries.[1]

Figure 3.2 depicts the technology breakdown of patents with two or more applicants filed under the Patent Cooperation Treaty (PCT) system for the period 1990-2010. Filings under the PCT system are not directly comparable to filings at national offices, as they only cover patents for which applicants seek protection in several countries. However, for the same reason, patents under the PCT are associated with more valuable inventions. The simple breakdown by technology – rather than industry – shows some similarity to findings in the US; co-patenting was most frequent in organic fine chemistry, computer technology and electrical machinery, followed by pharmaceuticals and basic material chemistry.

1 See Hagedoorn (2003). De Backer *et al.* (2008) report similar findings for patents filed at the European Patent Office. In addition, they show that "pharmaceuticals-biotechnology" and "chemical materials" have seen substantial increases in the share of patent filings with multiple applicants.

Normalizing co-patenting shares by total patent filings in given technology fields confirms the importance of co-patenting in chemistry. However, other top-ranked fields in this case include materials and metallurgy and semiconductors. In either case, Figure 3.2 shows that the top three technology fields account for less than a quarter of the total, indicating that co-patenting activity is relatively widespread.

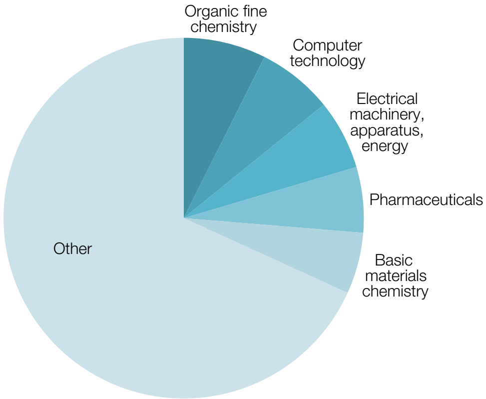
Even though sectoral patterns of co-patenting show some similarity to R&D alliance counts, the jury is still out as to how accurately co-patenting activity reflects underlying collaboration agreements (see Box 3.1). Studying this relationship at the firm level – while of interest in and of itself – could offer useful guidance on the appropriateness of employing co-patenting data as a measure of R&D collaboration.

Finally, neither R&D alliance counts nor co-patenting data offer any insight into the share of overall R&D that is undertaken collaboratively. The limited evidence discussed in Subsection 1.2.5 suggests that formal R&D collaboration is still relatively rare.

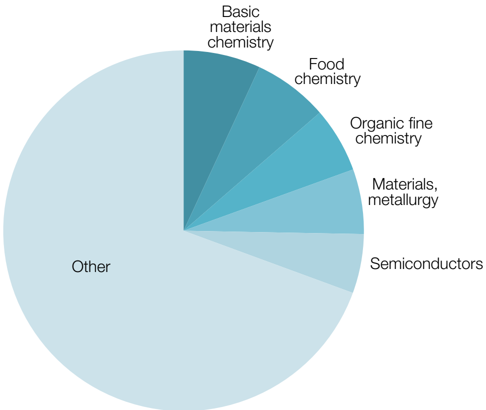
Figure 3.2: Co-patenting is widespread across technology fields

Distribution of PCT filings with two or more applicants, 1990 to 2010

(a) Absolute shares



(b) Shares normalized by total patenting in given technology field



Note: Co-patenting is defined as PCT filings with two or more applicants, where at least two of the applicants are not individuals, universities or public research organizations.

Source: WIPO Statistics Database, October 2011.

3.1.2

Why firms collaborate for strategic reasons

Collaboration may be strategically motivated. Alliances can provide a window onto the activities of competitors, giving firms information that could shape their R&D investment or product strategies. While alliance partners are typically careful to guard proprietary information – especially from competitors – it is difficult to obscure all sensitive information without choking off information flows completely. Such secrecy is hard to maintain with alliance partners and makes alliances useful for monitoring R&D activity.

In highly concentrated industries, firms might find the leakage of strategic information beneficial. Information shared within an alliance can provide useful signaling, and such disclosures may allow for tacit coordination. Indirect cooperation might include avoiding direct market competition, adopting common standards and coordinating product releases – particularly where product complementarities are strong.

Indeed, product complementarities can give firms compelling reasons to cooperate. Such interdependencies impact how technology producers think about investment. For example, it may not make sense to invest in technology for an external disk drive that enables faster writing than cable connection speeds would ever allow. Collaborating with technology developers of complementary products can help to coordinate investment schedules and promote interoperability in new product releases.

In some cases, firms may build alliances with partners they see as possessing complementary assets or skills that are important when technology under development reaches the commercialization phase. If producers of ideas anticipate that subsequent commercialization will require partnerships with those holding scarce, complementary assets, they may pursue collaboration to establish favored positions or agreements with potential allies.[2]

Alliances can be a means for improving efficiency, but they can also open the door to anticompetitive behavior. When joint ventures provide higher profits than noncooperative arrangements, the threat of a breakup can be used as an enforcing mechanism to sustain tacit collusion in product markets.[3] Alliances can also be vehicles by which two firms can coordinate a lowering of R&D investment such that both delay the introduction of new technologies in order to extend higher prices on existing technologies.[4]

2 See Teece (1986).
3 See Martin (1996).
4 See Cabral (2000).

3.1.3

How collaboration can improve efficiency

In addition to strategic motives, firms seek to collaborate to improve R&D efficiency – notably by benefiting from others' experience, dividing efforts, sharing risks and coordinating with producers of complementary goods. This subsection discusses each of these efficiency motives in turn.

First, as discussed in Subsection 2.2.2, knowledge is often cumulative, and obtaining the foundational knowledge required to pursue cutting-edge innovation is costly. Benefiting from the experience of others can be much cheaper than obtaining the same experience firsthand. The time required to attain a PhD and to become a seasoned scientist or technologist is lengthening as the "burden of knowledge" grows.[5] Firms with complementary expertise can benefit by sharing. Collaborating with other firms can be a way to leverage others' experience without being locked into a commitment to build up knowledge internally. This option is particularly useful when exploring new markets, geographical regions or technologies.[6]

Sometimes, firms are interested not only in leveraging the capabilities and accumulated knowledge of partner firms, but also in learning from them. Collaborative arrangements may explicitly be put into place to facilitate knowledge spillovers between partners (see also Subsection 2.2.4).

Second, teaming up to *divide efforts* can provide efficiency gains where two firms want to explore the same area. In particular, cost sharing is an important reason for joining forces. R&D investment such as the cost of laboratories, instrumentation, testing equipment and technical specialists can be substantial. In some industries, such as those producing semiconductors and telecommunications equipment, the cost of a single R&D project can require investment that is so high that it is beyond the reach of most companies.[7] In the more typical case of smaller-scale R&D operations, effective facilities require not only direct laboratory equipment but also ancillary services – for example, administrative support, maintenance staff that can handle specialized equipment or hazardous materials, testing technicians and others. Collaborating with another player with similar needs helps to spread these costs.

Third, R&D is a risky, exploratory process; not all efforts result in ideas that can be commercialized (see also Chapter 2). In areas like pharmaceuticals, the development of successful products only emerges out of many unfruitful attempts. Collaborating with others during the exploration phase spreads development risk over multiple firms, making it feasible to undertake riskier projects. R&D project portfolios are similar to financial security analogues: firms pursue multiple projects with the understanding that some will fail, but that high-value projects will compensate for that. However, unlike the losses associated with poor security performance, unfruitful projects have a silver lining: researchers learn something about the problem and can use that knowledge to more accurately target successful outcomes. While the cost of this learning must be borne once, the lessons learned can have multiple uses if shared.[8]

5 See Jones (2009).
6 See Veugelers (1998).
7 See Hagedoorn (1993).
8 For more basic research, such lessons can sometimes also be applied to projects unrelated to the objectives of the project initially commissioned.

Fourth, for firms with complementary offerings or R&D, cooperation can yield efficiency gains. In addition to the benefits of sharing knowledge and investment burdens, firms can coordinate by aligning their development programs. For example, cooperation on interface development can provide assurances with regard to interoperability as well as coordination in releasing new, improved technologies.

Collaboration for the development of new ideas can be doubly beneficial. First, the problem of underinvestment in R&D due to the appropriability dilemma introduced in Chapter 2 can be partially addressed through cost sharing; firms are more likely to invest sufficiently if the burden can be shared through partnerships. Second, joint activities facilitate knowledge spillovers, which is beneficial from a social welfare perspective. Some economists have advanced these twin benefits as reasons why joint R&D may warrant more favorable consideration by competition authorities (see also Section 3.3).[9]

3.1.4

The complications that arise in joint R&D undertakings

The preceding subsection described four rationales for collaboration based on efficiency gains: benefitting from the experience of others; dividing efforts; sharing risk; and coordinating with producers of complementary goods. For each of these rationales, conflicts of interests may arise.

First, in the case of disclosure, conflicts of interest may arise because individual firms seek to maximize their learning gains and minimize spillover leakages. It can be difficult to ascertain which information a partner firm chooses to withhold.[10] Empirical studies measuring joint venture failure rates have linked conflict of interest to collaboration viability; where partners compete in product markets, the failure rate of joint ventures increases markedly.[11]

In the second case – dividing efforts – monitoring R&D efforts can be difficult, in particular evaluating whether researchers are working hard or moving slowly. Conflicts of interest may arise because, while both parties benefit from the outcome of the joint effort, each has an incentive to let the other party do most of the work. This can be particularly pronounced where many partners are involved. Since it is difficult to both monitor R&D efforts and link each partner's contribution to the results of a joint venture, partners may exert less effort and free-ride on the work of others (see Box 3.2 for an example).[12]

9 See, for example, Grossman and Shapiro (1986) and Ordover and Willig (1985).
10 See Teece (1986).
11 See Harrigan (1988) and Kogut (1988).
12 See Deroian and Gannon (2006) and Goyal and Moraga-Gonzalez (2001).

Box 3.2: Conflict of interest in a pharmaceutical research alliance

In 1978, ALZA, a California-based drug company, and Ciba-Geigy, a large Swiss pharmaceutical firm, entered into a research agreement. In particular, Ciba-Geigy acquired a majority equity stake in ALZA and contracted the firm to conduct research. However, ALZA maintained activities with other parties which exploited technologies unrelated to the joint venture with Ciba-Geigy. Ciba-Geigy possessed significant control over ALZA – it had 8 out of 11 board seats, majority voting control, extensive information rights and the decision rights to guide 90% of ALZA's research activity through review panels which were mostly controlled by Ciba-Geigy employees. Despite such formal control rights, numerous conflicts arose regarding the kind of activities ALZA researchers participated in. Ciba-Geigy was particularly concerned about "project substitution", whereby ALZA scientists would devote too much time to other efforts outside their contract. Detailed accounting and monitoring of time had been stipulated in the contract, but delays in approving outside activities resulted in ALZA scientists circumventing the formal process.

Over time, Ciba-Geigy became increasingly concerned that its partner might misappropriate research results for extraneous use. As a result, it was reluctant to share information with ALZA. This disclosure problem, along with tensions related to control over outsideresearch, eventually led to the termination of their partnership at the end of 1981.

Source: Lerner and Malmendier (2010).

In the case of risk sharing, partners with a higher tolerance of risk might conceal this prior to joining a partnership. Even those partners who are risk averse may take on more risk with joint venture resources – a phenomenon economists refer to as moral hazard. Sharing cost exposure with partners can even lead to both parties taking on higher gambles, increasing the likelihood of alliance failure.

Lastly, product or technology complementarities expose partners to so-called holdup risk.[13] Joint development of complementary assets can provide mutual benefits, but partners may shape development in a way that locks in their technologies to the exclusion of others. Such strategic maneuvers to embed switching costs also represent a loss in social welfare, since consumers might be offered an inferior technology.

In the case of R&D alliances, Table 3.1 describes both the aligned objectives and conflicts of interest among collaborators and between technology producers and consumers.

Table 3.1: Aligned objectives and conflicts of interest in R&D alliances

	Aligned objectives	Conflicts of interest
Among producers of technologies	• Sharing experiences • Spreading costs • Spreading development risk • Coordinating the production of complementary products	• Free riding • Risk shifting and moral hazard • Holdup risk
Between technology producers and consumers	• Cost reduction • Ensuring compatibility among products	• Higher prices/less variety due to market power • Possible collusion to slow introduction of new technologies

Monitoring a partner's behavior can be difficult if not impossible. The connection between research effort and outcome is typically loose, making pay-for-performance contracting difficult to specify – especially where R&D is exploratory in nature. In addition, too much surveillance can have a chilling effect on knowledge exchange (see also Box 3.2) – the heart of what makes an R&D joint venture valuable in the first place.

13 See Gilbert (2010).

To the extent that contractual joint collaboration can be troublesome, firms may choose to create a third independent entity for which parents hold equity stakes. By using this arrangement, incentives are better aligned since both partners have a stake in the success of the third entity. Joint management and oversight make monitoring easier, and the ongoing relationship facilitates enforcement of good behavior. When contracting becomes more hazardous, independent management can be a more effective governance mechanism. One study that examines the organizational choice between contracting and equity joint ventures across national boundaries, finds that contracting risks are higher where enforcement of IP rights is more difficult.[14]

However, the equity form of organization is not without its own costs. Forming a separate entity is expensive, and the cost of "excessive bureaucracy" may outweigh the contracting hazards.[15] In addition, conflicts of interest may arise where joint venture activities affect the profits of one or more of its members.

3.1.5

How collaboration differs in the case of open source software

The previous subsection discussed the complications arising in R&D alliances, implicitly assuming that partnering firms rely on IP exclusivity to appropriate their R&D investments. However, does exclusivity always have to play such a central role in R&D collaboration? Open source software development provides an important instance that appears to challenge this position.

Open source software development involves developers – either individuals or firms, from a variety of locations and organizations – voluntarily sharing code to develop and refine computer programs which are then distributed at no or low direct cost.[16] What makes open source so revolutionary is that it challenges the assumption that IP exclusivity is necessary to motivate the production of new and useful ideas – in clear contradiction to the appropriability dilemma highlighted by Kenneth Arrow (see Section 2.1). In addition, open source software development has shown that collaboration for innovation can happen without IP exclusivity.

14 See Oxley (1999).

15 See Oxley (1997, 1999). The appropriateness of these organizational choices has been linked to performance outcomes. Sampson (2004) examines joint R&D activity with varying levels of opportunism risk. She uses transaction cost economics to predict that collaboration with higher risks for opportunism should adopt equity joint venture structures. Alternatively, straightforward collaboration may most efficiently be managed using contracts. Sampson finds that those alliances that fail to align governance mechanisms with the threat of opportunism underperform compared to those that do align.

16 See Lerner and Schankerman (2010) for a detailed treatment of the economics of open source software.

Open source software development has undoubtedly grown in influence. The number of such projects has increased rapidly: the website SourceForge.net, which provides free services to open source software developers, has grown from a handful of projects ten years ago to over 250,000 today.[17] Open source is attracting attention in the public sector as well. Government commissions and agencies have proposed – and in some cases implemented – a variety of measures to encourage open source developers, including R&D support, encouragement of open source adoption, explicit open source preferences in government procurement, and even obligations regarding software choices.[18]

Systematic evidence on the effects of open source development on firm performance, consumers and economic growth is still in its infancy. Existing studies suggest that both producers and users of open source products often blend participation in open source and proprietary software. In the case of producers, it is common for firms to develop both proprietary and open source programs.[19] Such mixing is likely to create cost savings, whether in product development or marketing. Firms may also participate in open source software projects strategically to upset dominant players. Similarly, adopters of open source software use open source and proprietary products side by side. Users vary a great deal, both in their software needs and in how they evaluate costs. Although proprietary software may cost more upfront, the costs of switching, interoperability and support services can be greater for open source products. The comingling of proprietary and open source programs in both production and use suggests a complementarity between the approaches.

What drives participation in open source software projects? Unlike in other open innovation models (see Subsection 1.2.5), compensation for innovative open source efforts is not critical to success. At the same time, Lerner and Tirole (2005) argue that contributions to open source efforts are not inexplicable acts of altruism but can be explained by other incentives. For example, participating in open source projects can enhance the skills of contributors, and these improvements may translate into productivity gains in paid work. Open source projects may also provide some intrinsic benefit if such projects are more interesting than routine employer-assigned tasks. Finally, open source participation could give coders a chance to showcase their talents to future employers.

Finally, the spread of open source software development evokes the question whether similar practices are transferable to other industries. Indeed, models of the open source type have been applied to other innovative activity.[20] However, their uptake appears less spectacular than for software. One explanation may be that the success of open source software is closely linked to the special circumstances of software development: projects can be broken into small, manageable and independent modules; input by geographically dispersed developers can be easily shared; upfront capital costs are limited; and new products do not face lengthy regulatory approval processes.[21] Nonetheless, additional opportunities for open source types of collaboration may well arise in the future as technology and the nature of innovation evolve.

17 *http://sourceforge.net/about* (accessed March 21, 2011).
18 See Lewis (2007).
19 See Lerner and Schankerman (2010) and Lyons (2005).
20 See, for example, Maurer (2007).
21 See Lerner and Tirole (2005).

3.2

Collaborating to commercialize existing IP

Collaboration between firms extends beyond the joint production of IP. In many cases, firms only join forces when or even after they commercialize their technologies. This section focuses on such cooperation. It first describes what motivates firms to collaborate during the commercialization phase and the conflicts of interest that may arise between them. It then discusses two specific forms of collaboration: patent pools and standard-setting organizations (SSOs).

3.2.1

Why complementarities require coordination

Innovative activity typically builds on previous innovation, and takes place simultaneously with similar innovative efforts by competing firms (see Subsection 2.2.2). In such an environment, so-called patent thickets may emerge: relevant IP rights are distributed over a fragmented base of IP holders, and those who wish to introduce products using such technologies face the high cost of negotiating with multiple parties. If each technology is essential, a negotiation failure with any of the IP holders is equivalent to a failure with all. New products are blocked, all IP holders lose an opportunity to commercialize and society misses out on new technology. Even in the case where an enterprising entrepreneur could strike a deal with each separate IP right holder, he or she is likely to overpay if the number of IP holders that could claim infringement is sufficiently large. Economists refer to this form of overcharging as “royalty stacking”.[22]

One potential solution for IP owners is to offer a license for their collective IP as a package. On the face of it, this form of collaboration would seem to benefit everyone. Suppliers can unlock the value of their IP holdings at a higher profit, and consumers benefit from new technology. However, as in the case of IP-generating collaboration, conflicts of interest invariably arise making it difficult for IP holders to agree on a deal; challenges also exist in balancing the interests of IP producers with the public good. Table 3.2 describes the aligned objectives and conflicts of interest in these two cases.

22 See Lerner and Tirole (2007).

Table 3.2: Aligned objectives and conflicts of interest in coordinating fragmented IP ownership

	Aligned objectives	Conflicts of interest
Among producers of complements	• Coordinate compatibility on collective offering • Manage the evolution of technological advance within the pool or standard • Accelerate technology adoption	• Compete for share of joint license revenues • Reduce alternatives of one's own technology, while increasing the substitutability of others • Increase competition by reducing transaction costs
Between technology producers and consumers	• Minimize adoption risk • Lower integration costs across complementary offerings	• Scope of interoperability with rival offerings providing complementary benefits • Introduction of greater choice of suppliers through more open standards

The following subsections discuss how patent pools and standard-setting institutions work to reconcile some of these conflicts.

23 However, the identification of patent pools underlying the data used in Figure 3.3 relied mostly on English language publications. The data may thus be biased towards US pools. The Data Annex provides further details.

24 The linkage between increased scrutiny by US federal regulatory agencies and the diminished number of patent pools should be interpreted with caution, as patent pool activity not captured by news sources or regulatory reports may have occurred during the intervening time.

3.2.2

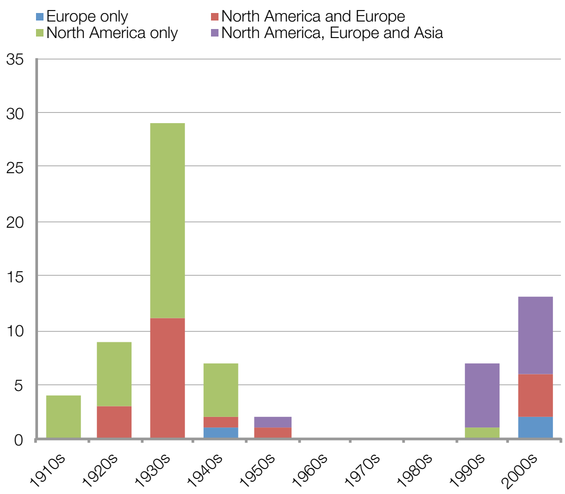
How firms collaborate in patent pools

Patent pools are organizations through which patent owners can share their patents with others, sometimes licensing them to third parties as a package. The terms of the patent pool agreement may specify licensing fees, the distribution of returns among the participants and the obligations of contributors regarding the use of their present and future patent rights. Patent pools can be seen as a market-based solution to the patent thicket problem. A firm's share in joint licensing revenue may be better than the revenue the firm could generate by licensing its patents individually. For consumers, such coordination brings technologies to market that would otherwise stay in the laboratory.

Available data suggest that patent pools have historically been concentrated in Europe and the United States (US).[23] Many date to the earlier half of the 1900s (see Figure 3.3). In the period after the Second World War, a more stringent regulatory environment viewed many patent pools as anticompetitive, which diminished the entry of new pools.[24] In the last decade, however, clearer pronouncements on the part of the US and European competition authorities have encouraged the creation of patent pools once again. More recently, Asian participation in patent pools has increased, reflecting their growing role in technological innovation. In addition, the ICT industry – broadly defined – accounts for the majority of patent pools established over the last two decades (see Figure 3.4).

Figure 3.3: The popularity of patent pools varies over time

Number of patent pools by country/ region

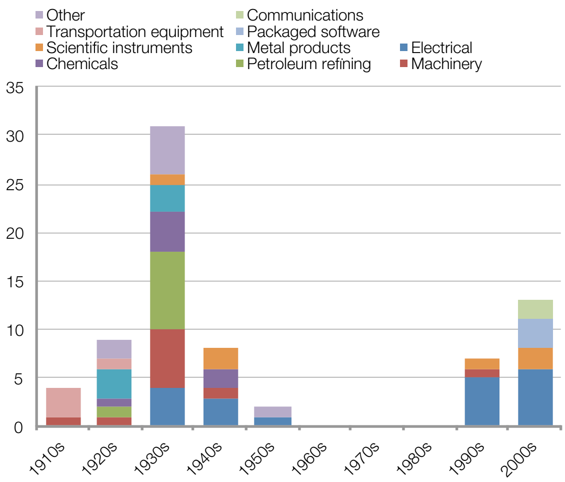


Note: Based on information for 75 documented pools. See the Data Annex for further details.

Source: Updated from Lerner *et al*. (2007).

Figure 3.4: The ICT industry dominates the recent wave of patent pools

Number of patent pools by industry



Note: Based on information for 75 documented pools.

Source: Updated from Lerner *et al*. (2007).

Notwithstanding the compelling rationales for IP holder cooperation, conflicts of interest can complicate the successful formation of patent pools. By lowering transaction costs and facilitating the commercialization of technologies, pools may intensify product market competition among members, leading to reduced profit margins.[25] Depending on their business model, members may also have different views on the design of pools. For example, pools can bring together players who participate in retail markets with those who only produce IP. Those who participate in retail market would be interested in trading lower licensing fees for cheaper access to the pool's IP, while pure R&D players might more likely aim to maximize licensing fees since they cannot recover their outlay through product sales. Pure R&D actors might prefer the broadest possible adoption, while competitors in retail markets may seek to exclude rivals. Box 3.3 offers an example of such conflicts of interest.

Box 3.3: Conflicts of interest in the MPEG-2 patent pool

The MPEG-2 patent pool offers an example of the complexities of cooperating with firms of varying levels of vertical integration. Contributing firm Sony also intended to license MPEG-2 patents; it was interested in maximizing the adoption rate of the standard. On the other hand, Columbia University and Lucent sought to maximize licensing revenues, since they did not participate in the downstream product market. Interestingly, the latter two acted in very different ways. Columbia University chose to participate in the pool for fear that negotiation failure would foreclose its hopes to gain any licensing revenue. Lucent, however, opted to withdraw from the pool. The firm believed that its two patents were critical to the MPEG-2 standard and that the pool's licensing fees were too low. Equipped with a sizable internal licensing department, Lucent was convinced that it could charger higher licensing fees independently.

Source: Lerner and Tirole (2007).

25 See Gilbert (2010).

As in the case of contractual partnerships and joint ventures, a second conflict of interest arises where pool members seek to maximize their return at the expense of consumers. Patent pools that charge too high a price effectively lower social welfare for the enrichment of pool members. Social welfare may also diminish if incentives to innovate are reduced. Pool members that enjoy monopoly status may have less incentive to release improved versions of their technologies, and their market power could raise barriers to entry for those who might step forward with better alternatives (see also the discussion in Subsection 2.2.3).

Should pools be allowed as a market-based solution to the coordination problem, or disallowed as a vehicle for collusion? The general principle is that competitive markets serve society's interest; however, complementarities present a special case for which coordination needs to be considered. The short answer is "it depends". Patent pools comprising complementary patents can be welfare-enhancing, because they solve the coordination problem. On the other hand, patent pools containing substitute technologies are not, since their main is to soften price competition among pool members.[26] Unfortunately, this is far from a clear litmus test in real situations; patents are rarely perfect complements or perfect substitutes.

One way to better differentiate beneficial pools from harmful ones is to look at the detailed provisions governing them. Two types of provisions are particularly relevant: so-called grant backs and independent licensing rules.

Grant backs commit pool members to offer future patents to the pool at no fee if such patents are deemed relevant to the patent pool.[27] This prevents individual members who patent technologies that become essential to the pool from holding up other members; it may also remove the incentive to hide development in progress. However, there is a cost to implementing such terms. Grant backs also lower the incentives to invest in future innovation; this not only works against the interests of pool members but also against the public interest. Policymakers need to be particularly concerned about grant backs restricting technological progress.

Independent licensing rules allow any pool member to license their patent outside of the pool. These can work in the public interest in at least three ways. First, the outside option to license the patents independently puts a ceiling on the fees the pool can charge. As mentioned earlier, in the absence of cooperation and where each IP holder licenses independently, royalty stacking may create inefficiently high prices. Certainly, policymakers would not want pool prices to be higher than this. Allowing pool members the option to independently license limits the bundled price to the sum of the independent licensing fees.

Second, independent licensing can serve as a screening device for policymakers to separate anticompetitive pools with substitute patents from beneficial pools of complementary patents. In anticompetitive pools, the freedom of members to license their technology independently would break the pool's ability to fix prices above the competitive rate. Such pools would therefore not include independent licensing provisions. On the other hand, independent licensing does not negatively impact pools of complementary patents, since external licensing of any component is either not valuable without the remaining complements or occurs in a market that does not compete with the pool.[28]

26 However, Gilbert (2010) shows that substitute patents in a pool do not increase member profits if the pool also includes essential patents. In this case, the inclusion of substitute patents could affect the ability of the pool to influence the adoption of technologies that do not require the essential patents.

27 See Layne-Farrar and Lerner (2010).

28 See Lerner and Tirole (2004, 2007).

Third, independent licensing encourages alternative applications of patented technologies which may have alternative uses outside the patent pool. Independent licensing enables such multiuse patents to realize their potential rather than restricting them to pool-related licensing.[29]

Empirical research on patent pools has made some headway in assessing whether the above predictions hold true in the real world. One key empirical challenge is that patent pools are voluntary organizations, and the set of candidate patents for pooling is thus difficult to identify. One recent study overcame this challenge by focusing on patent pools emerging from standard-setting efforts.[30] Because SSOs typically identify all essential patents in a patent pool, the authors were able to construct the set of patents that could potentially be included in nine modern patent pools.

Using data on participating companies as well as the composition of the patent pools themselves, the study reports several interesting findings. First, using patents identified in a standard as the measure of potential participation, they find that most pools contain roughly one-third of eligible firms, underscoring the voluntary nature of patent pools. This finding also points out that the extent to which pools resolve the patent thicket problem is perhaps more limited in reality. Second, firms that are vertically integrated in both R&D and downstream product production are more likely to join a pool than are pure R&D players.

Third, the study examines the impact of royalty sharing terms. Where participants contribute patents of comparable value, it is more likely that sharing revenue based on the number of patents contributed will be accepted. Because sharing terms might be determined with the specific intent of attracting participation, the authors look at the subset of firms that join the pool after the terms were formed. They find that firms are less likely to join an existing pool that uses such numerical proportion rules.[31]

In relation to whether independent licensing can effectively screen for socially beneficial pools, another study analyzes 63 patent pools and finds support for the association between complementary patent pools and the existence of independent licensing provisions.[32] Since patent pools do not spell out whether they comprise either complementary or substitute patents, the study employs records of legal challenges to capture the extent to which pools reduce competition.[33] It finds that pools with complementary patents are more likely to allow for external licensing. In addition, among litigated pools, those without independent licensing are more likely to face more severe verdicts. These findings are consistent with the theory described earlier.

29 A possible fourth benefit of independent licensing rules is that they reduce incentives for "socially wasteful" inventive effort. Consider the "innovation for buyout" scenario, whereby an enterprising inventor produces a "me-too" innovation very similar to a patent contained in a patent pool. The entrepreneur pursues this marginal invention knowing that the patent pool member will purchase the entrepreneur's patent in order to remove the threat of being ousted from the patent pool. The effort to develop a me-too invention and prosecute this buyout strategy is socially wasteful, since it generates little new knowledge; the primary purpose of this tactic is essentially to blackmail pool members. Mandated independent licensing can provide a check on such wasteful practices. Such mandates limit the opportunity to accumulate excess profits within the pool, and this limits the potential reward for pursuing innovation for buyout strategies.

30 See Layne-Farrar and Lerner (2010).

31 Given that few pools have adopted other approaches to license revenue allocation, the study was unable to conduct similar tests with value-based allocation or royalty-free treatments for licensing. See Layne-Farrar and Lerner (2010).

32 See Lerner *et al.* (2007).

33 In particular, the study uses records of both private challenges and the memoranda from US federal prosecutions to formulate this measure. It considers both the occurrence of litigation and remedies in such cases to measure the likelihood that such pools have in fact reduced competition.

Finally, the same study shows that grant back provisions were more frequently used in complementary pools that allow for independent licensing. This finding also supports earlier arguments: grant back rules help remedy the holdup problem (see earlier discussion), which is more likely to arise in complementary pools.

3.2.3

Why patent pools are emerging in the life sciences

As described in the previous subsection, the ICT industry accounts for the majority of patent pools formed over the last two decades. However, as patenting becomes increasingly common in the life sciences, coordination concerns for navigating patent thickets are also emerging in the biotechnology industry.[34]

The incentives to create biotechnology patent pools are similar to those in other industries. Overlapping patent claims can block the commercialization and adoption of technologies. The prospect of high coordination costs can also dampen research efforts in the first place. Patent pools offer a mechanism by which IP holders can coordinate to remove such roadblocks.[35]

However, there are additional motives for considering patent pools in the life sciences. Patent pools can be created for philanthropic purposes (see Subsection 1.3.4). For example, the Public Intellectual Property Resource for Agriculture (PIPRA) patent pool for genetically modified rice brings together over 30 different IP owners. Its purpose is to make patented technologies available to less developed economies free of charge. Similarly, the UNITAID patent pool focuses on making medicines for diseases such as HIV/AIDS, malaria and tuberculosis available to countries in need.

Patent pools may be created as a commons for encouraging research. In 2009, GlaxoSmithKline contributed over 500 patents to a patent pool for the study of neglected tropical diseases. In contrast to the UNITAID pool which concentrates on product availability, the GlaxoSmithKline patent pool focuses on the accessibility of its stock of ideas.

34 See Verbeure *et al.* (2006).
35 See Lerner and Tirole (2004) and Verbeure *et al.* (2006).

Proponents of life science patent pools point out that pools can also be a means for setting standards. Following the example of the telecommunications industry, pools may be used to establish and legitimize, for example, standards for recognized genetic mutations.[36] They could also be used to codify best practice guidelines for genetic testing of particular diseases.[37]

While patent pools hold the potential to make technology more accessible – particularly to disadvantaged groups or countries – and to coordinate basic research efforts, the biotechnology industry is in the early stages of determining how best to use them. Resolving conflicts of interest is likely to be just as challenging, if not more so, as it is for other industries. At this stage, many pools appear to focus on more marginal technologies, which firms release at least in part because they are not part of their core business. Many patent pools have a largely philanthropic character; how patent pools will operate within the business models of the biotechnology industry remains to be seen.[38]

3.2.4

How firms cooperate to set standards

As described earlier, patent pools in the modern era have often been formed around certain standards. In fact, patent pools can be the governing arrangement for a standard-setting group.[39] This subsection takes a closer look at the standard-setting process, exploring where standards are important, the role SSOs play, and the conflicts of interest that arise in the setting of standards.

Standards become critical where interoperability is important. They define which devices will work with others and the technology that enables them to do so. They might also specify not only the component technology, but also the interface requirements between technologies. Such interface standards allow producers to focus on improving their own module without constantly revisiting interoperability.

The link between standards and patent pools arises from the fact that many standards are based on complementary technologies, often developed by different firms. Patent pools that set out how technologies covered by a particular standard can be accessed are therefore a natural vehicle for cooperation among firms. One of the first patent pools associated with a standard was the MPEG-2 video coding standard pool. In 1997, the US Department of Justice issued a business review letter favorably responding to a proposal to license patents essential to the MPEG standard as a package. This decision – along with the positive response in 1998 to the DVD standard patent pool proposal – set the template for patent pools that would not run afoul of US antitrust laws.[40]

36 See Van Overwalle *et al.* (2005).
37 See Verbeure *et al.* (2006).
38 See *The Lancet*, “Pharmaceuticals, Patents, Publicity… and Philanthropy?” (2009).
39 In the nine modern patent pools studied by Layne-Farrar and Lerner (2010) all were associated with standard-setting efforts.
40 See Gilbert (2004).

Standards can be particularly important in the early stages of technology adoption, because they can reduce consumer confusion in the marketplace. Where consumers are uncertain about which technology provides the broadest compatibility, the rate of adoption is lower. Standards provide some assurance that certain technologies will continue to be supported in the future through upgrades and complementary products; they therefore inform development efforts and consumer decisions. Where industries adhere to standards, consumers can mix and match the best technologies to suit their needs.[41]

Standard-setting based on patented technologies generally require voluntary participation by patent holders; thus, many of the concepts and findings discussed in Subsection 3.2.2 apply to the standard-setting process. However, one economic characteristic associated with standards further complicates incentives for cooperation and has important social welfare implications: network effects (see Box 3.4 for an explanation). In particular, there is much to be gained by embedding one's patent in a standard and a great deal to lose by being excluded from it. As a result, technology producers are keen to influence the standard-setting process in their favor.

Box 3.4: What are network effects and how are they related to standard setting?

Network effects occur where the value of a product increases as more people use it. The classic example is the fax machine: such a device is nearly worthless unless others own one; however, as more consumers adopt the technology, it becomes increasingly valuable.

For a product to effectively exploit network effects, prior standard setting is often necessary – as is the case for the fax machine. Producers aligned with the standard have the advantage of remaining in the market as is, whereas those who are not so aligned must bring their offerings into compliance. Indeed, producers with a head start may be able to build a market share that makes it increasingly attractive for subsequent producers and consumers to adopt their standard. This positive feedback loop is referred to as an "indirect network effect", whereby the consumer benefit of a standard depends on the number of producers that adopt the standard, and producers' profits in turn depend on the number of consumers.[42]

Scholars who study network effects point out that, although according to theory there will be one or a handful of standards in a given segment where network effects are present, it is not clear which ones will be selected. Theoretical models which assume that producers and consumers make irreversible sequential decisions, predict that those who influence standards first will have the most to gain. Yet in other models, standards emerge from producers' and users' expectations about the future. In either case, these theories point to a critical implication for both producers and policymakers: the final standard adopted may not be the best one, but rather the one advanced by early movers.[43] Clearly, producers of goods for which value depends on complementary technologies have a strong interest in shaping standards.[44]

When the stakes are this high, it is not clear whether open market competition will lead to the best standard. IP holders will act to advance their own interests. Failure to reach an agreement could result in no coordination, even where it would be in society's interest. Rather than "voting with their money", potential consumers may simply choose not to adopt a technology, and the fear of poor adoption rates becomes a self-fulfilling prophecy.

SSOs may intervene to facilitate coordination by providing a forum for communication among private firms, regulatory agencies, industry groups or any combination thereof. This can improve the chances of a cooperative agreement being reached in the first place.[45] In addition, market mechanisms may lead to an impasse or to failed adoption if important information on the technologies themselves is not taken into account. Standard-setting forums provide an outlet for such information to be considered.

However, coordination via standards organizations is not without its own challenges. Conflicts of interest in the formation of standards are somewhat analogous to those encountered for patent pools. Suppliers can withhold information about R&D in progress to steer the group toward their forthcoming patents. Similarly, suppliers can use the knowledge gained in the standard-setting process to adjust their patent claims such that they have greater power to hold up the group (see Box 3.5 for an example).[46]

Box 3.5: The case of Rambus and the Joint Electron Device Engineering Council

One controversial example of a patent claim amendment is the case of Rambus and the SSO, the Joint Electron Device Engineering Council (JEDEC). Founded in 1990 as a technology licensing company, Rambus was invited to join JEDEC shortly after its creation. Rambus dropped out of the SSO in 1996. By that time, it had had the opportunity to observe the SSO's proceedings and subsequently filed for patent continuations. Rambus claimed that the decision to file such continuations was independent from its participation in JEDEC; however, Rambus' patent claim language for these continuations meant that those adopting JEDEC's synchronous dynamic random access memory (SDRAM) standard risked infringing Rambus' patents.

In 2000, Rambus successfully filed an infringement suit against Infineon, claiming that its memory manufactured under the SDRAM standard infringed four of its patents. These patents were filed after 1997, but they were continuations of a patent application originally filed in 1990. Over the next decade, Rambus was the subject of an extensive investigation by the US Federal Trade Commission (FTC). The agency charged Rambus with antitrust violations originating from what was inferred to be its attempt to use knowledge gained while participating in JEDEC to strategically expand the scope of its patent claims. These claims were contested through the District Courts and the Court of Appeals for the Federal Circuit, until 2009 when the US Supreme Court rejected the FTC's final appeal.

Source: Graham and Mowery (2004) and FTC Docket No. 9302. *www.ftc.gov/os/adjpro/d9302/index.shtm*

In a close examination of the US modem industry, one study finds that patent efforts may be the result, not the antecedent, of participation in standard-setting activities.[47] The study documents a high correlation between patents granted for modem technology and participation in standard setting. In addition, it finds that participation in standard-setting predicts subsequent patents granted, yet prior patents granted in the modem field are not indications of subsequent participation in standard setting.[48] These effects hold even when accounting for anticipated lags between patent applications and grants. While it is possible that companies lobby for technologies that they have not yet invented, the authors point out that such a strategy is risky, because another company may learn about the impending standard and overtake them in the patenting race.

45 See Farrell and Saloner (1988).

46 A different conflict of interest arises in the case of interface standards: firms can adopt "one-way" technical standards in which the interface on one side is openly disclosed but concealed behind a "translator" layer on the other. Such maneuvers allow some firms to enjoy protected positions within the standard while exposing others to competition.

47 See Gandal *et al.* (2007).

48 In particular, Gandal *et al.* (2007) employ a Granger causality test. In a nutshell, this test establishes that X "causes" Y if lagged values of X are significant in explaining outcome Y, where lagged values of Y are also included as controls.

Finally, there may also be conflicts of interest between SSOs and society. Notably, SSO members may charge higher royalties to non-members than to fellow members. One may argue that this would not be in the SSO's interest, as it could discourage wider adoption of a standard. However, there are more subtle means of creating disadvantages for non-members. For example, delaying disclosure can severely raise costs in a rapidly developing industry, harming competitive market forces (see Box 3.6 for an example).

Box 3.6: Delayed disclosure in the case of the Universal Serial Bus standard

One prominent example of delayed disclosure concerns the development of the Universal Serial Bus (USB) 2.0 standard. USB 2.0 improved speeds of the peripheral-to-computer connections by as much as 40 times. USB 2.0 was only compatible with a new controller interface, the Enhanced Host Controller Interface (EHCI). Consortium members like NEC Technologies, Lucent and Phillips all announced their new USB 2.0 and EHCI-compliant host controllers well in advance of the full release of the EHCI specification. In the fast-moving market of consumer electronics, such a head start can create a significant competitive advantage.

Source: MacKie-Mason and Netz (2007).

In the presence of network externalities, standards help to increase societal welfare through the mutual adoption of an agreed path for technological development. However, the same network externalities can trap society in an inferior standard (see also Box 3.4). Even were society to be better off collectively absorbing the cost of upgrading to another technology standard, no single firm may have the incentive necessary to initiate such an upgrade.[49] Private incentives may thus be insufficient for ensuring socially optimal outcomes.[50] This raises the question of which organizational attributes of SSOs best serve the public interest and the appropriate form and level of government intervention in the standard-setting process. Difficult trade-offs exist. For example, it may seem more efficient to decide on standards quickly; converging on this allows producers to focus on performance improvements rather than standard-setting. On the other hand, encouraging more competition among alternative standards prior to selection could help to ensure that the best standard emerges.

3.3

Safeguarding competition

The previous discussion pointed to a number of situations in which private collaborative practices may conflict with society's interests. In particular, collaborative practices can curtail the functioning of market competition to the extent that consumers face higher prices, lower output, less choice, the adoption of second-best technologies and reduced innovation.

There is thus a role for competition policy to play in identifying and prohibiting those collaborative agreements which impose a net cost on society. Indeed, in many countries, competition policy addresses the interface between private collaboration, IP and competition. While there are important differences across jurisdictions, most policy frameworks explicitly recognize that collaboration can promote societal welfare; they are thus generally permissive of collaborative practices, unless they trigger certain warning signs. Even then, only a few collaborative practices are expressly prohibited – mainly those associated with the formation of hardcore cartels. In most cases, such warning signs prompt authorities to further examine the competitive consequences of collaborative agreements.

49 See Farrell and Saloner (1985).
50 See Katz and Shapiro (1985).

Competition policy frameworks often spell out in some detail the types of agreements that raise concerns in the national context. This section reviews some of the key rules and guidelines that have emerged in a number of jurisdictions – namely, the European Union (EU), Japan, the Republic of Korea and the US.[51] The discussion is not meant to be comprehensive from a legal viewpoint, but merely seeks to illustrate the different approaches and key legal concepts applied. Following the structure of the previous discussion, the section first looks at collaborative R&D alliances, followed by patent pools and standard-setting agreements.

3.3.1

The type of collaborative R&D alliances that may be considered anticompetitive

There are three types of criteria that competition agencies employ to identify potentially anticompetitive collaborative R&D alliances: whether the combined market share of participants exceeds certain concentration thresholds; how the joint research undertaking might affect market competition; and whether an agreement includes certain provisions that may be unduly harmful for competition.

First, several jurisdictions have established critical market share thresholds above which collaborative agreements may trigger closer scrutiny by competition authorities. For example, EU guidelines refer to a combined market share threshold of 25 percent. In Japan and the Republic of Korea, similar thresholds stand at 20 percent. Competition authorities in the US do not employ a market share threshold, but use threshold values for a broader measure of market concentration, in particular the Herfindahl-Hirschman Index.[52]

Implementing such threshold criteria is often not straightforward, as authorities need to define what constitutes a relevant market. One possibility is to define markets in relation to a specific technology – for example, combustion engines. Other options are to define markets in relation to specific products and their close substitutes – for example, car engines – or broader consumer markets – for example, cars. Further complications arise where R&D agreements concern radically new technologies that have no close substitutes. Competition authorities sometimes calculate market shares using alternative market definitions, though the precise practice varies across countries.

51 See guidelines on joint research practices for the EU (2010, 2011), Japan (1993, 2007), the Republic of Korea (2007, 2010) and the US (1995, 2000). The US Department of Justice and Federal Trade Commission (2007) reported and reviewed the practices in this field.

52 The Herfindahl-Hirschman Index is calculated by summing the squares of individual firms' market shares thereby giving proportionately greater weight to the larger market shares.

Second, in assessing the competitive consequences of collaborative agreements, some competition authorities look at the nature of the joint research undertaking. In Japan, for example, an agreement is more likely to raise concerns the closer the joint research activity is to the commercialization stage. Similarly, US competition authorities are more circumspect of agreements that assign marketing personnel to an R&D collaboration. In the EU, R&D agreements that cover basic research are less likely to raise concerns than agreements covering the production and marketing of research results. In addition, many competition authorities are more lenient towards agreements involving firms that clearly possess complementary assets and for which the rationale for collaboration is thus strongest.

Finally, the inclusion of certain provisions in collaborative R&D agreements may trigger action by competition authorities. As already pointed out, provisions that facilitate the formation of hardcore cartels – notably, price-fixing, market sharing or joint marketing – are illegal *per se* in most countries. In addition, authorities may investigate agreements that impose restrictions on collaborating partners which could result in reduced innovative activity. For example, in the EU and Japan, authorities may question agreements that limit participants' research activity in areas different from those of the joint project, or that takes place after the joint project is completed. In addition, EU authorities may challenge agreements that do not allow all participants access to the results of the joint research or that prevent participants from exploiting research results individually.

3.3.2

How competition rules treat patent pools and standard-setting agreements

As pointed out in Subsection 3.2.2, competition authorities have become more lenient towards the formation of patent pools in the last two decades, which partly explains their historical resurgence (see Figure 3.3). Nonetheless, they still scrutinize such agreements for potential anticompetitive effects.

As in the case of collaborative R&D alliances, most jurisdictions prohibit agreements that facilitate the formation of hardcore cartels, that is, participants jointly determining prices or quantities in product markets. In addition, many competition frameworks may question agreements that unduly slow innovative activity and, interestingly, they sometimes employ the criteria outlined in Section 3.2.

Specifically, in the US, provisions that discourage participants from engaging in further R&D – for example, through grant back obligations – may be considered anticompetitive.[53] In the Republic of Korea and Japan, authorities may challenge agreements that do not allow for independent licensing. In addition, EU, Korean and US authorities may investigate patent pools if the technologies included are seen as substitutes.

Relatively few countries have developed detailed competition rules on the treatment of patent rights in standard-setting agreements, although certain business practices by patent holders may be covered by general competition law principles such as price gouging or refusal to deal. Nonetheless, competition policy frameworks in some countries address the patent-standards interface. Thus, in the Republic of Korea, standard-setting agreements that disclose only limited patent information or that do not spell out the detailed licensing conditions affecting participants may be considered anticompetitive.

53 At the same time, the US Department of Justice has expressly considered grant back provisions in its business review letters, without rejecting them.

Similarly, China's Standardization Administration has issued draft rules requiring patent holders to disclose their patents if they are involved in standard-setting or if they are otherwise aware that standards under development cover a patent they own. These rules also foresee that patents relevant to a national standard be licensed either free-of-charge or at a below-normal royalty rate.[54]

54 See Standardization Administration of the People's Republic of China (2009).

3.4

Conclusion and directions for future research

Firms increasingly look beyond their own boundaries to maximize their investment in innovation. From society's perspective, private collaboration promises clear benefits: it encourages knowledge spillovers; promotes an efficient division of labor; reduces innovation risks; and fosters the interoperability of complementary products. However, leaving the formation of collaboration arrangements to private market forces may not lead to socially optimal outcomes; firms may either collaborate below desirable levels or they may do so in an anticompetitive manner.

Insufficient levels of collaboration may occur where there are conflicts of interest between potential collaborators. Fears of free riding, risk shifting and other forms of opportunistic behavior may lead firms to forgo mutually beneficial cooperation. Differences in business strategies between specialized R&D firms and vertically integrated R&D and production firms may contribute to negotiation gridlock.

In principle, the failure of private markets to attract an optimal level of collaboration provides a rationale for government intervention. Unfortunately, economic research provides no universal guidance to policymakers on how such market failures are best resolved. This is partly because the benefits of and incentives for collaboration are highly specific to technologies and business models, and also because it is difficult to evaluate how many potentially fruitful collaboration opportunities go unexplored in different industries.

Some governments promote collaboration through fiscal incentives for firms and related innovation policy instruments. In addition, there are incentive mechanisms for sharing IP rights – for example, discounts on renewal fees if patent holders make their patents available for licensing. However, as greater technological complexity and a more fragmented IP landscape have increased the need for collaboration, there is arguably scope for creative policy thinking.

The problem of anticompetitive collaborative practices seems easier to address from a policymaker's viewpoint. Such practices are generally more observable, and authorities can assess the competitive effects of collaborative agreements on a case-by-case basis. In addition, some consensus exists about the type of collaborative practices that should not be allowed or at the least trigger warning signs. For instance, the inclusion of grant back provisions and restrictions on independent licensing have emerged as differentiating markers between beneficial versus potentially anticompetitive agreements.

Nonetheless, evaluating the competitive effects of specific collaborative agreements remains challenging – especially where technologies move fast and their market impact is uncertain. In addition, many low- and middle-income countries have less developed institutional frameworks for enforcing competition law in this area – although they may benefit from the enforcement actions of high-income countries where most collaborative agreements with global reach are concluded.

Areas for future research

Seeking a better understanding of how collaborative practices involving IP affect economic performance is a fertile area for future research. In guiding policymakers on how best to balance cooperation and competition in the generation of new ideas, further investigation in the following areas would seem especially helpful:

- Much of the available evidence on collaborative R&D alliances is based on case studies. This partly reflects the fact that the impact of these alliances is critically dependent on specific business strategies and technology properties, but it also reflects inadequate data. Collecting more and better data through carefully designed firm surveys could generate more systematic evidence of the patterns, motives and effects of collaborative R&D, thereby usefully complementing the available case study evidence.

- The economic literature provides only limited guidance on situations in which governments should consider intervening in market processes for selecting standards. This is a long-standing policy question, and countries have opted for markedly different approaches. Clear-cut answers may seem elusive; however, it would be useful to further investigate the effects of the different structures and decision-making rules of SSOs on the speed and quality of standard adoption where underlying IP landscapes are highly fragmented.

- Little insight exists on the effectiveness of government programs that support collaboration. For example, as pointed out above, many patent offices offer incentives to patent owners for making their patents available for licensing; no research has sought to systematically evaluate whether such incentives matter and, if so, how. More generally, no research exist on how other elements of the IP system – above all, firms' prospect of effectively enforcing IP rights – affects incentives for different forms of collaboration.

- As many collaborative agreements have a global reach, national enforcement of competition law is bound to have international spillovers. However, the precise extent and nature of these spillovers is not well understood. Generating evidence on this question would be important in assessing the need for low- and middle-income countries to further develop competition rules in this area.

- Finally, available evidence on collaborative practices focuses almost entirely on high income countries. In the case of patent pools, this may be because many of the patent families behind patent thickets do not extend to low- and middle-income countries – though this is an important research question in its own right. In the case of R&D alliances, innovation surveys in middle income countries suggest that local firms do collaborate frequently. However, no evidence is available to assess whether the motivations and effects of such collaboration differ systemically from high income countries.

REFERENCES

Arthur, W.B. (1989). Competing Technologies, Increasing Returns, and Lock-in by Historical Events. *The Economic Journal, 99*(394), 116-131.

Bresnahan, T.F. & Yin, P. (2007). Standard Setting in Markets: The Browser War. In S.M. Greenstein and V. Stango (Eds.), *Standards and Public Policy.* Cambridge: Cambridge University Press, 18-59.

Cabral, L.M.B. (2000). R&D Cooperation and Product Market Competition. *International Journal of Industrial Organization, 18*(7), 1033-1047.

Carlson, S.C. (1999). Patent Pools and the Antitrust Dilemma. *Yale Journal on Regulation, 16*, 359-399.

Commerce Clearing House. (various years). Trade Regulation Reporter. New York: Commerce Clearing House.

Dahlander, L. & Gann, D.M. (2010). How Open is Innovation? *Research Policy, 39*(6), 699-709.

De Backer, K., Lopez-Bassols, V. & Martinez, C. (2008). Open Innovation in a Global Perspective – What do Existing Data Tell Us? *OECD STI Working Paper, 2008/4*.

Deroian, F. & Gannon, F. (2006). Quality-Improving Alliances in Differentiated Oligopoly. *International Journal of Industrial Organization, 24*(3), 629-637.

Dun and Bradstreet (yearly). Who Owns Whom. In Dun and Bradstreet WorldBase (Ed.).

European Commission. (2010). Commission Regulation No. 1217/2010 on on the Application of Article 101(3) of the Treaty on the Functioning of the European Union to Certain Categories of Research and Development Agreements.

European Commission. (2011). Communication from the Commission: Guidelines on the Applicability of Article 101 of the Treaty on the Functioning of the European Union to Horizontal Co-Operation Agreements.

Fair Trade Commission Republic of Korea. (2007). Guidelines for Cartel Review.

Fair Trade Commission Republic of Korea. (2010). Review Guidelines on Undue Exercise of Intellectual Property Rights.

Farrell, J. & Klemperer, P. (2007). Coordination and Lock-in: Competition with Switching Costs and Network Effects. *Handbook of Industrial Organization, 3*, 1967-2072.

Farrell, J. & Saloner, G. (1988). Coordination through Committees and Markets. *The RAND Journal of Economics, 19*(2), 235-252.

Federal Trade Commission & US Department of Justice. (2000). *Antitrust Guidelines for Collaborations Among Competitors.*

Gandal, N., Gantman, N. & Genesove, D. (2007). Intellectual Property and Standardization Committee Participation in the US Modem Industry. In S.M. Greenstein and V. Stango (Eds.), *Standards and Public Policy.* Cambridge University Press, 208-230.

Gilbert, R.J. (2004). Antitrust for Patent Pools: A Century of Policy Evolution. *Stanford Technology Law Review, 3*, 7-38.

Gilbert, R.J. (2010). Ties that Bind: Policies to Promote (Good) Patent Pools. *Antitrust Law Journal 77*(1),1-48.

Goyal, S. & Moraga-Gonzalez, J.L. (2001). R&D Networks. The RAND *Journal of Economics, 32*(4), 686-707.

Graham, S. & Mowery, D. (2004). Submarines in Software: Continuations in U.S. Software Patenting in the 1980s and 1990s. *Economics of Innovation and New Technology, 13*, 443-456.

Grossman, G.M. & Shapiro, C. (1986). Optimal Dynamic R&D Programs. *The RAND Journal of Economics, 17*(4), 581-593.

Hagedoorn, J. (1993). Understanding the Rationale of Strategic Technology Partnering: Inter-organizational Modes of Cooperation and Sectoral Differences. *Strategic Management Journal, 14*(5), 371-385.

Hagedoorn, J. (2002). Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. *Research Policy, 31*(4), 477-492.

Hagedoorn, J. (2003). Sharing Intellectual Property Rights—An Exploratory Study of Joint Patenting amongst Companies. *Industrial and Corporate Change, 12*(5), 1035-1050.

Harrigan, K.R. (1988). Strategic Alliances and Partner Asymmetries. In F. Contractor and P. Lorange (Eds.), *Cooperative Strategies in International Business*. Lanham: Lexington, 205-226.

Japanese Fair Trade Commission. (1947, amended 2009). Act on Prohibition of Private Monopolization and Maintenance of Fair Trade (Act no. 54 of April 14, 1947).

Japanese Fair Trade Commission. (1993, updated in 2009). Guidelines concerning Joint Research and Development under the Antimonopoly Act.

Japanese Fair Trade Commission. (2007). Guidelines for the Use of Intellectual Property under the Antimonopoly Act.

Jones, B.F. (2009). The Burden of Knowledge and the"Death of the Renaissance Man": Is Innovation Getting Harder? *Review of Economic Studies, 76*(1), 283-317.

Kaysen, C. & Turner, D.F. (1965). *Antitrust Policy: An Economic and Legal Analysis.* Cambridge: Harvard University Press.

Kogut, B. (1988). A Study of the Life Cycle of Joint Ventures. In F. Contractor and P. Lorange (Eds.), *Cooperative Strategies in International Business*. Lanham: Lexington Books, 169-186.

Langlois, R.N. (2007). Competition through Institutional Form: The Case of Cluster Tool Standards. In S.M. Greenstein and V. Stango (Eds.), *Standards and Public Policy.* Cambridge: Cambridge University Press, 60-86.

Layne-Farrar, A. & Lerner, J. (2011). To Join or Not to Join: Examining Patent Pool Participation and Rent Sharing Rules. *International Journal of Industrial Organization, 29*(2), 294-303.

Lerner, J. & Malmendier, U. (2010). Contractibility and the Design of Research Agreements. *The American Economic Review, 100*(1), 214-246.

Lerner, J. & Schankerman, M. (2010). *The Comingled Code: Open Source and Economic Development.* Boston: MIT Press.

Lerner, J., Strojwas, M. & Tirole, J. (2007). The Design of Patent Pools: The Determinants of Licensing Rules. *The RAND Journal of Economics, 38*(3), 610-625.

Lerner, J. & Tirole, J. (2004). Efficient Patent Pools. *The American Economic Review, 94*(3), 691-711.

Lerner, J. & Tirole, J. (2005). The Economics of Technology Sharing: Open Source and Beyond. *The Journal of Economic Perspectives, 19*(2), 99-120.

Lerner, J. & Tirole, J. (2007). Public Policy toward Patent Pools. *Innovation Policy and the Economy, 8*, 157-186.

Lewis, J.A. (2007). Government Open Source Policies. *Center for Strategic and International Studies.*

Link, A. (2005). Research Joint Ventures in the United States: A Descriptive Analysis. In A. N. Link & F. M. Scherer (Eds.), *Essays in Honor of Edwin Mansfield*. New York: Springer, 187-193.

Lyons, D. (2005). Has Open Source Become a Marketing Slogan? *Forbes.*

MacKie-Mason, J.K. & Netz, J.S. (2007). Manipulating Interface Standards as an Anticompetitive Strategy. In S.M. Greenstein and V. Stango(Eds.), *Standards and Public Policy.* Cambridge: Cambridge University Press, 231-259.

Martin, S. (1996). R&D Joint Ventures and Tacit Product Market Collusion. *European Journal of Political Economy, 11*(4), 733-741.

Maurer, S. (2007). Open Source Drug Discovery: Finding a Niche (or Maybe Several). *University of Missouri at Kansas City Law Review, 76*(1-31).

Merges, R.P. (1999). As Many as Six Impossible Patents before Breakfast: Property Rights for Business Concepts and Patent System Reform. *Berkeley Technology Law Journal, 14*, 557-616.

Merges, R.P. (1999). Institutions for Intellectual Property Transactions: The Case of Patent Pools. *University of California at Berkeley Working Paper.*

Ordover, J.A. and Willig, R.D. (1985). Antitrust for High-technology Industries: Assessing Research Joint Ventures and Mergers. *Journal of Law and Economics, 28*(2), 311-333.

Oxley, J.E. (1997). Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach. *Journal of Law, Economics, and Organization, 13*(2), 387-409.

Oxley, J.E. (1999). Institutional Environment and the Mechanisms of Governance: The Impact of Intellectual Property Protection on the Structure of Inter-firm Alliances. *Journal of Economic Behavior and Organization, 38*(3), 283-309.

Pharmaceuticals, Patents, Publicity… and Philanthropy? (February 2009). *The Lancet*, *373*, 693.

Sampson, R.C. (2004). Organizational Choice in R&D Alliances: Knowledge-Based and Transaction-Cost Perspectives. *Managerial and Decision Economics, 25*(6-7), 421-436.

Schilling, M.A. (2009). Understanding the Alliance Data. *Strategic Management Journal, 30*(3), 233-260.

Shapiro, C. (2000). Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting. *Innovation Policy and the Economy, 1*, 119-150.

Standardization Administration of the People's Republic of China. (2009). Regulations on Administration of Formulating and Revising National Standards Involving Patents.

Teece, D. (1986). Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy, 15*(6), 285-305.

US Department of Justice & Federal Trade Commission. (1995). Antitrust Guidelines for the Licensing of Intellectual Property.

US Department of Justice & Federal Trade Commission. (2007). Antitrust Enforcement and Intellectual Property Rights: Promoting Innovation and Competition.

Van Overwalle, G., van Zimmeren, E., Verbeure, B. & Matthijs, G. (2005). Models for Facilitating Access to Patents on Genetic Inventions. *Nature Reviews Genetics, 7*(2), 143-154.

Vaughan, F.L. (1925). *Economics of Our Patent System.* New York: The Macmillan Company.

Vaughan, F.L. (1956). *The United States Patent System: Legal and Economic Conflicts in American Economic History.* Norman: University of Oklahoma Press.

Verbeure, B., van Zimmeren, E., Matthijs, G. & Van Overwalle, G. (2006). Patent Pools and Diagnostic Testing. *TRENDS in Biotechnology, 24*(3), 115-120.

Veugelers, R. (1998). Collaboration in R&D: An Assessment of Theoretical and Empirical Findings. *De Economist, 146*(3), 419-443.

War and Peace and the Patent System (1942). *Fortune, 26*, 102-105,132,134,136,138,141.

DATA ANNEX

R&D alliances

The SDC Platinum, CORE and MERIT-CATI databases are the three most used sources for measuring R&D-specific alliances between firms across technology fields and industrial sectors.

The SDC Platinum database is maintained by Thomson Reuters and provides information on financial transactions between firms, including merger and acquisition (M&A) activity. Data on alliance activity, a section of the M&A, capture a wide range of collaborative agreements, including agreements between industrial partners on distribution, licensing, manufacturing, marketing, R&D, sales and supply, as well as joint ventures and strategic alliances. They also comprise of alliances between governments and universities. The data shown here represent the count of R&D alliances classified in one of the following four categories: R&D alliances, cross-licensing, cross-technology transfer and joint ventures. Information is collected based on Security and Exchange Commission (SEC) filings, trade publications as well as news sources.

The Cooperative Research (CORE) database, from the National Science Foundation (NSF), collects information on industrial partnerships which are filed under the National Cooperative Research and Production Act (NCRPA) in the US. Disclosure of any research and/or production collaboration with other firms under the NCRPA limits the possible antitrust liabilities arising from those activities. NCPRA filings are published in the Federal Register and include information on R&D partners as well as partnership objectives. The CORE database catalogues those filings and is further described in Link (2005).

The MERIT-CATI database refers to Cooperative Agreements and Technology Indicators (CATI) alliance data administered by the UNU Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT) in the Netherlands. Information on agreements that cover technology transfer – including joint research agreements and joint ventures involving technology sharing between two or more industrial partners – is collected on a worldwide basis. It relies on print publications including newspapers, company annual reports, the Financial Times and Who Owns Whom, published yearly by Dun and Bradstreet. Further description of the database is available in Hagedoorn (2002).

These databases are likely to capture only a fraction of the total instances of collaboration between firms worldwide. One weakness is that they predominantly cover R&D alliances documented in English-language publications, although the MERIT-CATI database also includes announcements in Dutch and German. The language bias also limits the geographical coverage of collaborative agreements. By definition, the CORE database covers only US agreements.

Patent pools

The patent pool data presented in this chapter were kindly supplied by Josh Lerner and Eric Lin from the Harvard Business School. They build on an earlier database described in Lerner *et al*. (2003), since updated to 2010.

No official reporting requirement exists for patent pools. One therefore needs to rely on a variety of secondary sources to track the formation of such pools. The patent pool database relies on a variety of English-language publications, reports by US government agencies, and company news releases. Some of these publications include Carlson (1999), Commerce Clearing House (various years), Kaysen and Turner (1965), Merges (1999), Vaughan (1925, 1956) and Fortune (1942). The coverage of pools is clearly biased towards those formed in the US. However, even for the US the data may be incomplete.

Patent pools are defined as patent-based collaborative agreements of the following two types: (i) at least two firms combine their patents with the intention to license them, as a whole, to third parties; and (ii) at least three firms come together to share their patents among themselves. The count of patent pools captured here does not include cross-licensing agreements, new entities established to manufacture products based on different firms' IP, firms that acquire patents and license them to interested parties, or patent pools dominated by non-profit entities (such as universities).

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

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

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

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

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

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

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

1 The text mostly covers universities and PROs. At times, the term "public research institutions" is used to cover both of the above. It must be noted that the exact definition of what falls under "PROs and universities" varies from country to country.

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

4.1

The evolving role of universities and PROs in national innovation systems

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

4.1.1

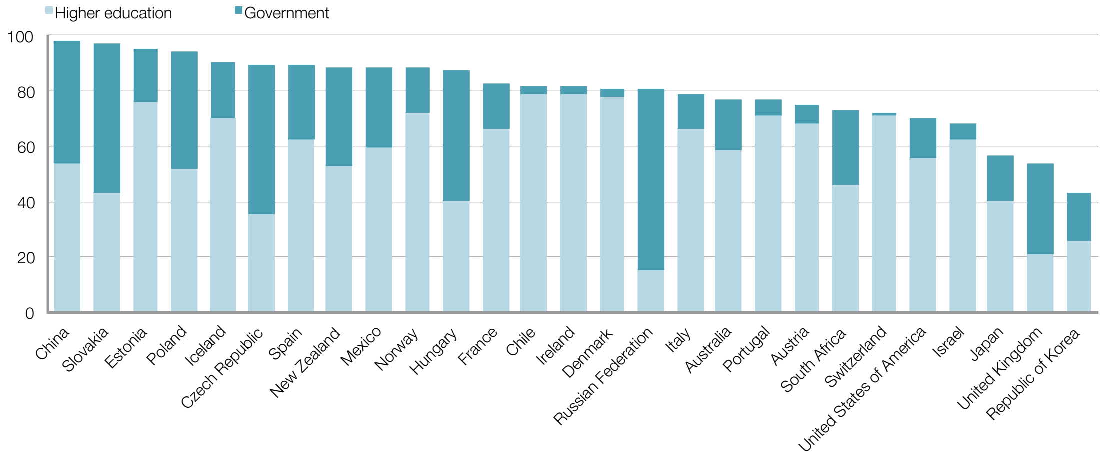
Public R&D is key, in particular for basic research

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

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

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

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



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

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

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

4 See OECD, Research & Development Statistics. Depending on the country in question, it accounts for about 40 percent (Republic of Korea) to close to 100 percent (Slovakia) of all basic research performed.

5 See OECD (2008b).

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

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

4.1.2

Public R&D stimulates private R&D and innovation

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

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

Box 4.1: The economic impact of publicly-funded research

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

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

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

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

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

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

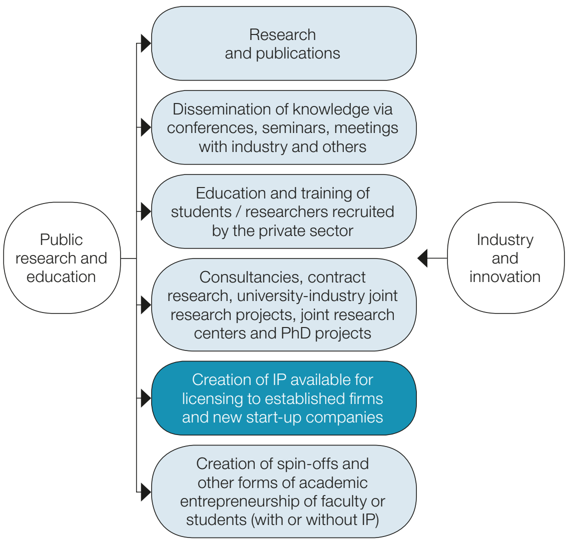
Although this chapter focuses on the role of intellectual property (IP), public-private knowledge transfer occurs through a large number of formal and informal channels, and IP issues are only one part of the bigger landscape. Figure 4.2 sets out the following informal and formal channels of exchange:[17]

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

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

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

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



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

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

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

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

4.1.3

Fostering the impact of publicly-funded research on innovation

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

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

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

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

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

4.2

Public research institutions' IP comes of age

4.2.1

Developing policy frameworks for technology transfer

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

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

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

Box 4.2: A short history of university technology transfer legislation

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

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

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

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

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

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

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

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

A review of existing mechanisms reveals a few important lessons. First, despite the general trend towards institutional ownership and commercialization of university and PRO inventions, a diversity of legal and policy approaches persists, both in terms of how such legislation is anchored in broader innovation policy (see Box 4.2) as well as how it is designed with respect to specific rules on the scope of university patenting, invention disclosure, incentives for researchers (such as royalty sharing) and whether certain safeguards are instituted to counteract the potentially negative effects of patenting (see Subsection 4.4.1 and Section 4.5).[38] Second, the means to implement such legislation, as well as the available complementary policies to enhance the impact of public R&D and to promote academic entrepreneurship, vary widely (see Section 4.3).

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

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

36 See Basant and Chandra (2007).

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

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

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

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

4.2.2

Measuring the increase in university and PRO patenting

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

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

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

40 See Khan and Wunsch-Vincent (2011).

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

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

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

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

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

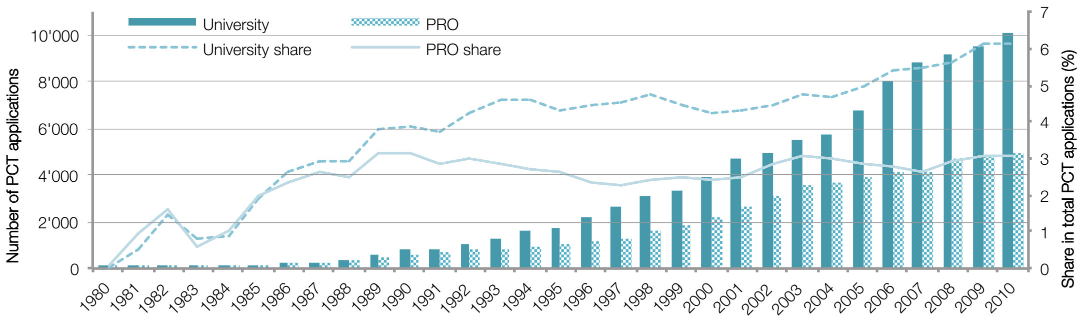
Since 1979, the number of international patent applications filed under the PCT by universities and PROs has been steadily increasing, except for a drop in 2009 linked to broader economic conditions. In fact, these university and PRO filings have grown faster than total PCT applications over the period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

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

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

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

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



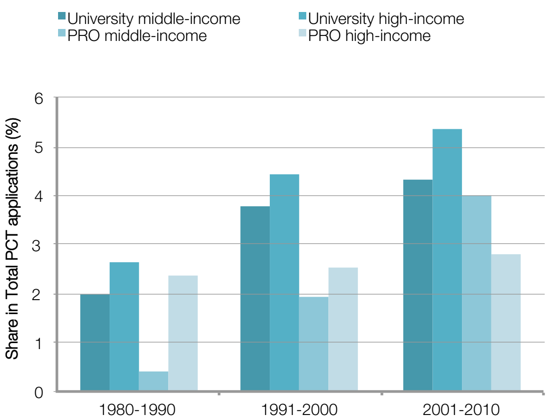
Note: As noted in footnote 1, the distinction between universities and PROs often depends on the definition in a given country. The same note applies to the figures which follow.

Source: WIPO Statistics Database, June 2011.

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

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

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



Source: WIPO Statistics Database, June 2011.

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

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

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

Figure 4.5: US and Japan lead in university PCT applications

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

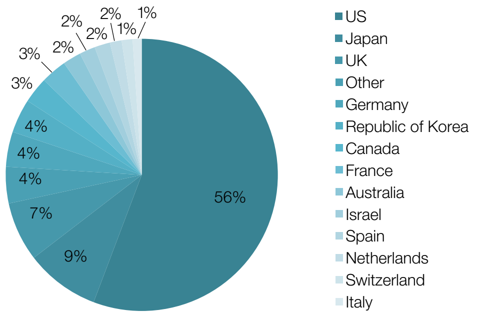
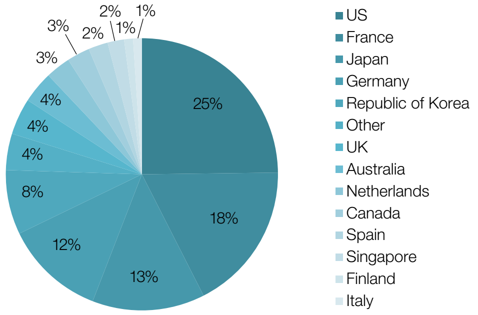


Figure 4.6: US, France and Japan lead in PRO PCT applications

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



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

Source: WIPO Statistics Database, June 2011.

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

Figure 4.7: China and Brazil lead in university PCT applications

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

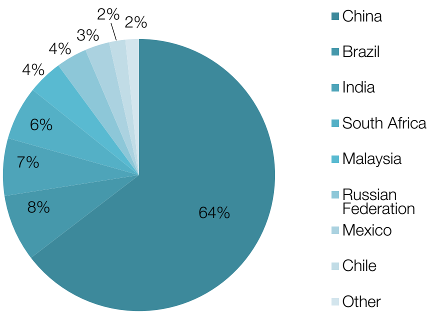
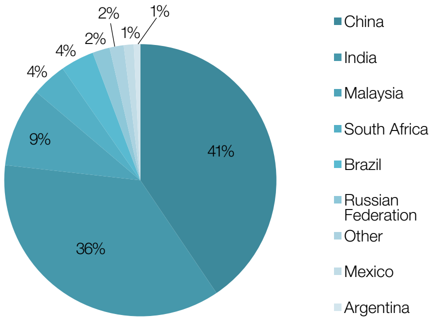


Figure 4.8: China and India lead in PRO PCT applications

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



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

Source: WIPO Statistics Database, June 2011.

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

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

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

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

National patent filings of universities and PROs are more heterogeneous

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

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

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

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

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

Source: WIPO Statistics Database, June 2011.

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

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

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

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

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

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

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

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

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

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

48 See Japan Patent Office (2010).

49 See Korean Ministry of Knowledge Economy (2010).

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

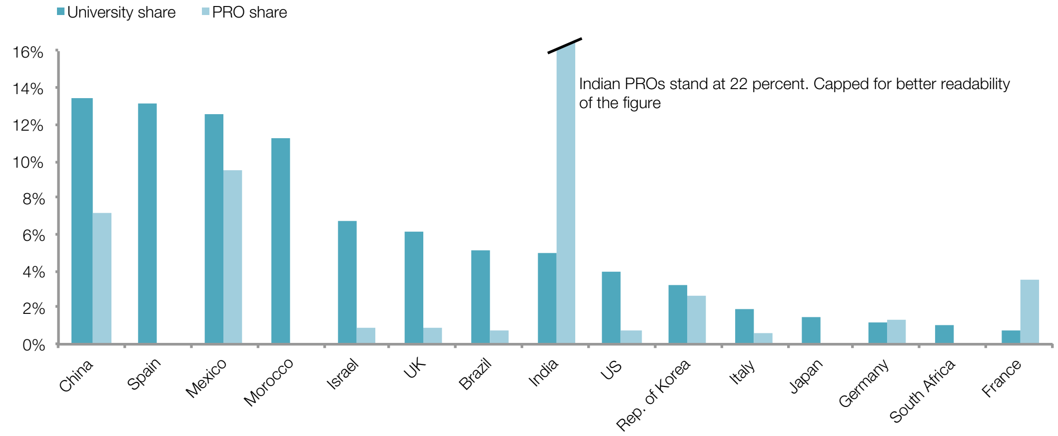
51 See NSF (2010). On average, and for all patents not limited to universities, about 42 percent of applications filed are granted by the United States Patent and Trademark Office (USPTO). See European Patent Office, Japan Patent Office, Korean Intellectual Property Office and USPTO (2009), "Four Office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

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

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

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

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



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

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

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

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

Technological fields of university and PRO patenting

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

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

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

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

4.2.3

University and PRO licensing growing but from low levels

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

60 See Conti and Gaulé (2011).

61 *Idem.*

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

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

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

Source: Commonwealth of Australia (2011).

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

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

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

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

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

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

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

Source: Wu (2010).

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

4.3

Assessment of impacts and challenges in high-income countries

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

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

4.3.1

Direction of impacts

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

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

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

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

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

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

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

- For universities, this set-up can lead to (i) increased IP ownership, facilitating academic and other entrepreneurship (including academic spin-offs) and vertical specialization; (ii) cross-fertilization between faculty and industry; and (iii) increased student intake and ability to place students in firms.

- For firms, it (i) facilitates the revelation of useful university inventions to the business sector; (ii) enables the creation of a market for inventions based on publicly-funded research; and (iii) can spur the commercialization of new products generating profits and growth.

- Positive systemic outcomes could include (i) increased impact of more research with the potential for application; (ii) improved innovation system linkages; (iii) a higher quality of research and education, in particular for science; (iv) greater commercialization of inventions; (v) positive impacts on entrepreneurship and local jobs; and (vi) for the wider economy, greater competitiveness in the global market.

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

According to this view, university research has been associated with the norms of rapid disclosure of research results and an environment of knowledge sharing, co-authorship and joint projects which contribute to cumulative learning. The patenting of university inventions and related conflicts of interest might, however, have negative influences on these norms; slow the diffusion of university inventions, including research tools; and stifle innovation.[72] The exclusive licensing of patents to single firms might, in particular, limit the diffusion of knowledge generated with public funds.

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

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

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

72 See Eisenberg (1989); Heller and Eisenberg (1998); and Kenney and Patton (2009). The latter authors note that the institutional arrangements within which TTOs are embedded have encouraged some of them to become revenue maximizers rather than facilitators of technology dissemination for the good of the entire society.

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

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

- For universities, this set-up can lead to (i) a diversion of time away from scientific research; and (ii) IP-related establishment and maintenance costs (which can howere also be seen as an investment).
- For firms, this could result in (i) potential barriers to access of university inventions; and (ii) increased IP-based transaction costs and tensions in industry-university relationships.
- Negative systemic impacts could include (i) a reorientation of the direction of research towards less diversity and an overemphasis on short-term, commercially-oriented research; (ii) negative impacts on open science; (iii) prospects of reduced government funding for public research, for science and for the economy more widely; (iv) long-run negative effect of diverting attention away from academic knowledge production; (v) long-run negative effects of IP on open science and follow-on innovation; and, finally, (vi) the fact that IP might inhibit rather than promote commercialization of inventions.

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

	Potential Benefits	Potential costs
Broader impacts on science	**1) Increased impact of more focused research with potential for application** **2) Improved innovation system linkages** • Efficient division of labor in the generation and commercialization of new inventions • Private sector contribution to funding basic and applied research **3) Increase in the quality of research and education**	**1) Reorientation of the direction of research** • Overemphasis on applied, short-term, more lucrative research • Less diversity in scientific disciplines as focus on patentable outcomes increases • Other university missions are neglected, such as teaching and training **2) Negative impacts on open science** • Crowds out/displaces the use of other knowledge transfer channels to industry • Publication delays, increased secrecy, less sharing, including the withholding of data • Decrease in international scientific exchanges **3) The promise of university income can reduce government commitment to funding**
Innovation and growth	**1) Commercialization of inventions with economic and social impacts** • Increase in consumer welfare and business productivity via access to innovative products and processes **2) (Localized) positive impacts on R&D, technology spillovers, entrepreneurship, employment and growth** **3) Higher competitive position of country in global market**	**1) Long-run negative effect of diverting attention away from academic knowledge production** **2) Long-run negative effects of IP on open science and follow-on innovation** • Patenting of broad upstream inventions, platform technologies and research tools increases the cost of follow-on research and innovation • Reduction in the diversity of research **3) Focus on IP might inhibit rather than promote commercialization of inventions**

4.3.2

Impacts and experiences in high-income countries

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

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

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

73 See Baldini (2006) and Larsen (2011).

74 See Goldfarb *et al.* (2011); Goldfarb *et al.* (2001); and Jensen and Thursby (2001).

75 See Boardman and Ponomariov (2009).

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

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

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

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

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

77 See OECD (2003).

78 See Aldridge and Audretsch (2010).

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

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

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

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

Evidence for wider economic impacts

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

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

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

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

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

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

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

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

80 See Roessner *et al.* (2009), cited in AUTM (2010). This widely cited study states that, over the last 30 years, more than 6,000 new US companies were formed on the basis of university inventions; 4,350 new university-licensed products entered the market; and these inventions made a USD187 billion impact on the US gross domestic product, with 279,000 jobs created. The authors argue that no attempt was made to valuate the other significant economic contributions of university-based research, and that estimates are therefore considered to be significantly conservative.
81 See Rosenberg and Nelson (1994).
82 See Azoulay *et al.* (2006) and Owen-Smith and Powell (2003).
83 See Aldridge and Audretsch (2010).
84 See Rosenberg and Nelson (1994) and Zucker *et al.* (1998).
85 Several major corporations began as TTO start-ups, including Genentech in biotechnology, Cirrus Logic in semiconductors, and Lycos in Internet search engines. See Di Gregorio and Shane (2003).
86 See Di Gregorio and Shane (2003) and Shane (2004).
87 See AUTM (2010).
88 In contrast, licensing to established firms is used to commercialize new technologies that are more incremental, codified, late stage and specific in purpose. They also tend to involve minor technical advances, provide moderate customer value and have weaker IP protection.

Box 4.5: Academic entrepreneurship stimulated by university inventions

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

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

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

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

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

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

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

Success factors for harnessing the knowledge from public research

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

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

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

- the location of the university in a dynamic region near innovative firms, venture capital, etc.;
- the size and type of the university, private universities with a commercial orientation being more active than public universities, for instance;
- the portfolio of disciplines, some of which are more prone to patenting than others;
- the research quality of the institution, its reputation and network;
- the extent of existing collaboration with a university and its entrepreneurial climate;
- organizational practices and an institutional culture which foster IP-based technology transfer;
- the establishment of institutional strategies for knowledge transfer and commercialization;

89 See Belenzon and Schankerman (2009).

- competitive faculty salaries and incentives to file for IP rights and to disclose inventions to a TTO, notably also with respect to whether patents are considered in the attainment of academic tenure;
- the characteristics of the relevant TTO (see Box 4.6);[90] and
- complementary factors and policies that encourage academic start-ups, such as allowing faculty to create and own a share in a start-up or to take a leave of absence, providing additional financing and support, and framework conditions such as incubators and science parks.

The required institutional, financial and human resources represent a sizeable investment by universities and PROs. The often volatile and skewed licensing income typically does not recover these costs. As a result, the idea that licensing could act as a potential substitute for other university income or other funding sources should be discarded.

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

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

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

Open questions include:

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

Beyond these factors, the evidence stresses the importance of a well-defined university IP policy. Universities with internal rules regulating the participation of researchers in the transfer of technology perform better than universities without such rules.[95] Well-defined university policies with clear rules on benefit sharing improve performance by giving researchers incentives to participate in the transfer of technology.[96] Rules that help to standardize relationships with potential licensees through standard forms and contracts also reduce transaction costs in finalizing agreements with the private sector. In addition, these policies can help address some of the concerns raised above, ensuring that universities and PROs – and their faculties – do not neglect their other major missions of teaching and research in the name of commercialization.

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

Substantiating the concerns about publicly-funded research

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

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

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

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

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

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

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

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

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

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

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

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

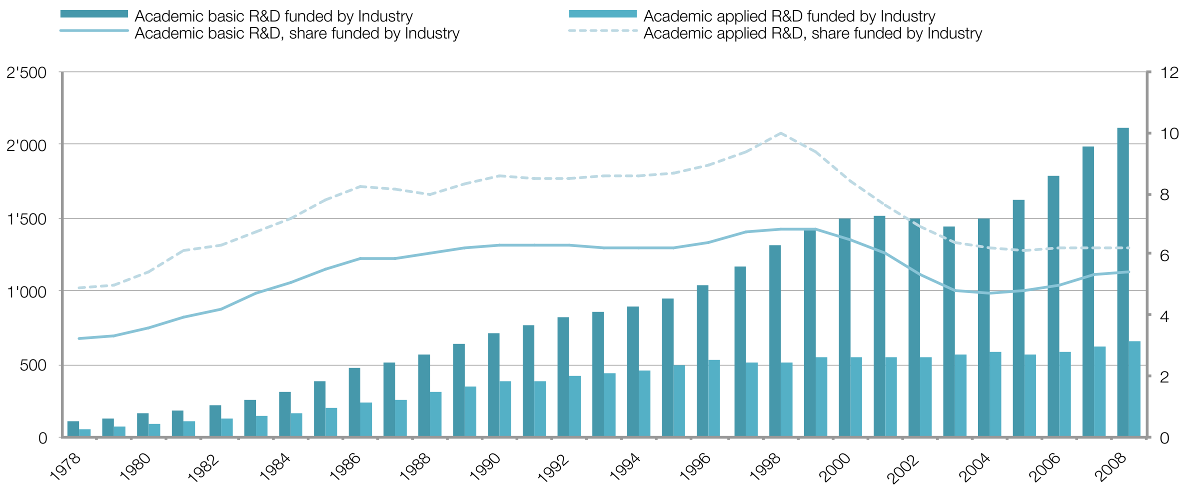
To put these findings into perspective, the data show that universities continue to account for the majority of basic and academic research, while pursuing little development. If anything, basic R&D as a percentage of gross domestic product (GDP) has increased or remained the same over time, including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

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

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

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

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



Note: Data for 2008 are preliminary.

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

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

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

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

110 See Sampat (2006).
111 See Walsh *et al.* (2005).
112 See Murray and Stern (2007).
113 One issue is that, depending on the country in question, research exemptions provide different degrees of flexibility in this regard. The exemptions, at times, also do not clearly seem to cover research tools, as opposed to other patented inventions.

Box 4.7: Of mice and academic freedom

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

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

Source: Murray *et al.* (2009)

4) Influences on university and industry relations: Anecdotal evidence from the US suggests that proactive university efforts to own results of co-sponsored research and to generate licensing income have become controversial (see Table 4.5).[114] The fact that universities insist on their own IP terms prior to working with industry has been framed as a barrier to collaboration, given the long delays and potential for friction where universities act to maximize profits.[115] Some frustration stems from the fact that universities may tend to deploy a "one-size-fits-all" approach to patenting research results, notwithstanding the evidence that patents and exclusive licensing play different roles in the development of complex versus discrete technologies (see Chapter 2).[116]

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

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

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

114 See Thursby and Thursby (2007) and Litan *et al.* (2008).
115 See Alexy *et al.* (2009) and Wadhwa (2011). Specific firms have argued that it has distanced universities from firms in the US and has been a reason for US firms to collaborate more with firms abroad. See Litan *et al.* (2008).
116 See So *et al.* (2008).
117 OECD MSTI.

4.4

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

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

Table 4.13 summarizes the various dimensions of the potential impacts.

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

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

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

Potential benefits	Potential costs
1) All the same benefits mentioned above (see Tables 4.5 and 4.6) • This depends, however, on the capacity to absorb and further develop university inventions – either by domestic firms or by locally present multinational firms – and on whether these inventions are at all relevant to low- and middle-income country needs **2) Ability to contribute to local or global markets for university inventions** • This depends on the capacity to generate university inventions and to file patents • University inventions might also attract the presence of multinational companies and their associated complementary R&D • The strengthened science-industry links can help reorient research towards local needs	**1) All the same above-mentioned costs (see Tables 4.5 and 4.6), some of which are amplified given the greater resource constraints of less developed economies** • Reduced or no access to critical technologies owned by universities in high-income countries • Overemphasis on applied, lucrative projects may lead to less useful inventions from the point of view of low- and middle-income countries • The decrease in international scientific exchanges and a reduced eagerness of institutions in high-income countries to collaborate as a result of more complex IP ownership issues and secrecy

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

4.4.1

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

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

In that context, the literature considers their reduced and more expensive access to knowledge.[119] One concern is that the patenting of scientific results in high-income countries could restrict access to research tools, databases and technologies.[120] In particular, stricter IP practices may hinder access to technologies that are particularly critical for less developed economies, for example in agriculture and health and for particular life-saving medications (see Section 4.5 in this regard, which suggests policies to counteract such impacts).[121]

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

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

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

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

4.4.2

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

129 See Zuñiga (2011).

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

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

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

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

4.5

New university policies act as safeguards

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

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

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

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

- First, the patenting and the licensing of particular inventions and technologies can be restricted. For instance, guidelines can demand that patents should be sought, and exclusive licenses attributed, only where they are a necessary condition for their commercialization. University policies and government bodies can also declare certain areas off-limits to university patenting: basic research, research tools, technologies critical to public health in low-income countries.
- Second, where inventions are patented, the type of and access to downstream licenses can be influenced by legislation or institutional policies. For instance, licensees of government-funded technologies can be required to disclose follow-on investment and the actual use of the patent, for instance avoiding that these patents are used to block follow-on inventions by incumbents or patent aggregators. Certain requirements can be instituted to ensure that products derived from these inventions are sold to consumers or poorer countries on reasonable terms.[130] Field-of-use restrictions can also be implemented to ensure that the IP is made available for future research, including to other firms. Governments can also reserve the right to practice the invention or override exclusive licensing rights ("march-in rights").

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

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

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

Box 4.8: "Nine Points to Consider in Licensing"

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

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

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

Table 4.12: University and PRO "open IP policies"

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

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

135 See Nill (2002).

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

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

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

4.6

Conclusions and directions for future research

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

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

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

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

Areas for future research

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

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

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

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

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

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

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

REFERENCES

Adams, J.D. (1990). Fundamental Stocks of Knowledge and Productivity Growth. *Journal of Political Economy, 98*(4), 673-702.

Aldridge, T. & Audretsch, D.B. (2010). Does Policy Influence the Commercialization Route? Evidence from National Institutes of Health Funded Scientists. *Research Policy, 39*(5), 583-588.

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

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

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

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

Baldini, N. (2006). University Patenting and Licensing Activity: A Review of the Literature. *Research Evaluation, 15*(3), 197-207.

Balme, P., Cytermann, J.-R., Dupont, J.-L., Guillaume, H., Langlois-Berthelot, M., Macron, E., de Malleray, P.-A. & Szymankievicz, C. (2007). *Rapport sur la valorisation de la recherche*. Paris: Ministère de l'Économie, de l'industrie et des finances.

Basant, R. & Chandra, P. (2007). University-Industry Link and Enterprise Creation in India – Some Strategic and Policy Issues. In Yusuf & Nabeshima (Eds.), *How Universities Promote Economic Growth.* Washington, D.C.: The World Bank, 209-226.

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

Belenzon, S. & Schankerman, M. (2010). Spreading the Word: Geography, Policy and University Knowledge Diffusion. *CEP Discussion Paper, CEPDP1005.*

Bishop, K., D'Este, P. & Neely, A. (2011). Gaining from Interactions with Universities: Multiple Methods for Nurturing Absorptive Capacity. *Research Policy, 40*(1), 30-40.

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

Breschi, S., Lissoni, F. & Montobbio, F. (2007). The Scientific Productivity of Academic Inventors: New Evidence from Italian Data. *Economics of Innovation and New Technology, 16*(2), 101-118.

Caballero, R.J. & Jaffe, A.B. (1993). How High are the Giants' Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth. In O.J. Blanchard & S. Fischer (Eds.), *NBER Macroeconomics Annual* (Vol. 8). Chicago: The University of Chicago Press, 15-74.

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

Campbell, E.G., Weissman, J.S., Causino, N. & Blumenthal, D. (2000). Data Withholding in Academic Medicine: Characteristics of Faculty Denied Access to Research Rsults and Biomaterials. *Research Policy, 29*(2), 303-312.

Cervantes, M. (2009). Academic Patenting: How Universities and Public Research Organizations are Using Their Intellectual Property to Boost Research and Spur Innovative Start-ups. Retrieved from *www.wipo.int/sme/en/documents/academic_patenting.html*

Chapple, W., Lockett, A., Siegel, D. & Wright, M. (2005). Assessing the Relative Performance of U.K. University Technology Transfer Offices: Parametric and Non-parametric Evidence. *Research Policy, 34*(3), 369-384.

Chokshi, D.A. (2006). Improving Access to Medicines in Poor Countries: The Role of Universities. *PLoS Medicine, 3*(6).

Chokshi, D.A. & Rujkumar, R. (2007). Leveraging University Research to Advance Global Health. *Journal of the American Medical Association, 29*(16), 1934-1936.

Clemente, F.-P. (2006). The Impact of Stronger Intellectual Property Rights on Science and Technology in Developing Countries. *Research Policy, 35*(6), 808-824.

Cohen, W.M. & Levinthal, D.A. (1989). Innovation and Learning: The Two Faces of R & D. *The Economic Journal, 99*(397), 569-596.

Commonwealth of Australia (2011). National Survey of Research Commercialization 2008 and 2009 – Selected Measures of Commercialisation Activity in Australia's Universities, Publicly Funded Research Agencies, Medical Research Institutes and Cooperative Research Centres. Canberra: Commonwealth of Australia.

Conti, A. & Gaule, P. (2011). Is the US Outperforming Europe in University Technology Licensing? A New Perspective on the European Paradox. *Research Policy, 40*(1), 123-135.

Craig Boardman, P. & Ponomariov, B.L. (2009). University Researchers Working with Private Companies. *Technovation, 29*(2), 142-153.

Crespi, G.A., Geuna, A., Nomaler, Ö. & Verspagen, B. (2010). University IPRs and Knowledge Transfer: Is University Ownership More Efficient? *Economics of Innovation and New Technology, 19*(7), 627-648.

Czarnitzki, D., Glänzel, W. & Hussinger, K. (2009). Heterogeneity of Patenting Activity and Its Implications for Scientific Research. *Research Policy, 38*(1), 26-34.

Czarnitzki, D., Hussinger, K. & Schneider, C. (2011). Commercializing Academic Research: the Quality of Faculty Patenting. *Industrial and Corporate Change.*

Dalmarco, G. & Freitas, d.M. (2011). Universities' Intellectual Property: Path for Innovation or Patent Competition? *Journal of Technology Management & Innovation, 6*(3).

Daraio, C., Bonaccorsi, A., Geuna, A., Lepori, B., Bach, L., Bogetoft, P. *et al.* (2011). The European University Landscape: A Micro Characterization Based on Evidence from the Aquameth Project. *Research Policy, 40*(1), 148-164.

Dasgupta, P. & David, P.A. (1994). Toward a New Economics of Science. *Research Policy, 23*(5), 487-521.

David, P.A. (2004). Can "Open Science" Be Protected from the Evolving Regime of IPR Protections? *Journal of Institutional and Theoretical Economics JITE, 160*(1), 9-34.

David, P.A. & Hall, B.H. (2006). Property and the Pursuit of Knowledge: IPR Issues Affecting Scientific Research. *Research Policy, 35*(6), 767-771.

David, P.A., Mowery, D. & Steinmueller, W.E. (1992). Analysing the Economic Payoffs from Basic Research. *Economics of Innovation and New Technology, 2*(1), 73-90.

Debackere, K. & Veugelers, R. (2005). The Role of Academic Technology Transfer Organizations in Improving Industry Science Links. *Research Policy, 34*(3), 321-342.

Di Gregorio, D. & Shane, S. (2003). Why Do Some Universities Generate More Start-ups than Others? *Research Policy, 32*(2), 209-227.

Du Plessis, M., Van Looy, B., Song, X. & Magerman, T. (2010). Data Production Methods for Harmonized Patent Statistics: Patentee Sector Allocation 2009. Brussels: Eurostat.

Edwin, M. (1991). Academic Research and Industrial Innovation. *Research Policy, 2*0(1), 1-12.

Eisenberg, R. (1989). Patents and the Progress of Science: Exclusive Rights and Experimental Use. *University of Chicago Law Review, 56*, 1017-1055.

Engel, N. (2008). University Patenting and its Effects: An Assessment for Developing Countries. In C. S. Krishna (Ed.), Technology Transfer: Intellectual Property Rights Hyderabad: Amicus Books/The Icfai University Press, 127-142.

European Commission (2008). Commission Recommendation on the Management of Intellectual Property in Knowledge Transfer Activities and Code of Practice for Universities and Other Public Research Organizations. Luxembourg: European Commission.

European Commission (2009). Expert Group on Knowledge Transfer – Final Report. In Directorate General for Research (Ed.). Brussels: European Commission.

Fabrizio, K.R. & Di Minin, A. (2008). Commercializing the Laboratory: Faculty Patenting and the Open Science Environment. *Research Policy, 37*(5), 914-931.

Foray, D. & Lissoni, F. (2010). University Research and Public-Private Interaction. In B.H. Hall & N.Rosenberg (Eds.), *Handbook of the Economics of Innovation* (Vol. 1). Amsterdam: North Holland, 275-314.

Geuna, A. & Nesta, L.J.J. (2006). University Patenting and Its Effects on Academic Research: The Emerging European Evidence. *Research Policy, 35*(6), 790-807.

Geuna, A. & Rossi, F. (2011). Changes to University IPR Regulations in Europe and the Impact on Academic Patenting. *Research Policy, 40*(8), 1068-1076.

Goldfarb, B., Henrekson, M., & Rosenberg, N. (2001). Demand vs. Supply Driven Innovations: US and Swedish Experiences in Academic Entrepreneurship. *SIEPR Discussion Paper, 0436.*

Goldfarb, B., Sampson, R.C. & Ziedonis, A.A. (2011). *Incentives or Resources? Commercialization of University Research by Start-Ups vs. Established Firms.* Paper presented at the DRUID 2011. Retrieved from *http://druid8.sit.aau.dk/druid/acc_papers/pejqk7endg416ljvit0t91ds0uac.pdf*

Graff, Gregory D., Bradford, Kent J., Zilberman, David & Bennett, Alan B. (2003). The Public-Private Structure of Intellectual Property Ownership in Agricultural Biotechnology. *Nature Biotechnology, 21*, 989-995.

Griliches, Z. (1980). R&D and the Productivity Slowdown. *The American Economic Review, 70*(2), 343-348.

Grimaldi, R., Kenney, M., Siegel, D.S. & Wright, M. (2011). 30 Years after Bayh-Dole: Reassessing Academic Entrepreneurship. *Research Policy, 40*(8), 1045-1057.

Guan, J.C., Yam, R.C.M. & Mok, C.K. (2005). Collaboration Between Industry and Research Institutes/Universities on Industrial Innovation in Beijing, China. *Technology Analysis & Strategic Management, 17*(3), 339-353.

Guellec, D., Madies, T. & Prager, J.-C. (2010). Les marchés de brevets dans l'économie de la connaissance. *Les Rapports du Conseil d'analyse économique*. Paris: Conseil d'analyse économique.

Gulbrandsen, M., Mowery, D. & Feldman, M. (2011). Introduction to the Special Section: Heterogeneity and University-Industry Relations. *Research Policy, 40*(1), 1-5.

Gupta , V.K. (2008). Indian Patent Output 1990-2007. *India, Science and Technology: 2008. S&T Output and Patents.* New Delhi: National Institute of Science, Technology and Development Studies.

Heller, M. & Eisenberg, R. (1998). Can Patents Deter Innovation? The Anticommons in Biomedical Research. *Science, 280*, 698-701.

Inspection générale des finances (2007). Rapport sur la valorisation de la recherche, *Pour le Ministère de l'économie, des finances et de l'industrie et le Ministère de l'éducation nationale, de l'enseignement supérieur et de la recherche*. Paris.

Jaffe, A. B. (1989). Real effects of academic research. *The American Economic Review, 79*(5), 957-970.

Japan Patent Office (2010). J*apan Patent Office Annual Report.* Tokyo: Japan Patent Office.

Jensen, R., Thursby, J. & Thursby, M.C. (2010). University-Industry Spillovers, Government Funding, and Industrial Consulting. *National Bureau of Economic Research Working Paper Series, No. 15732.*

Jensen, R. & Thursby, M. (2001). Proofs and Prototypes for Sale: The Licensing of University Inventions. *The American Economic Review, 91*(1), 240-259.

Just, R.E. & Huffman, W.E. (2009). The Economics of Universities in a New Age of Funding Options. *Research Policy, 38*(7), 1102-1116.

Kapsynski, A., Crone, T.E. & Merson, M. (2003). Global Health and University Patents. *Science, 301*, 1629.

Kenney, M. & Patton, D. (2009). Reconsidering the Bayh-Dole Act and the Current University Invention Ownership Model. *Research Policy, 38*(9), 1407-1422.

Khan, M. and S. Wunsch-Vincent. (2011). Capturing Innovation: The Patent System. In S. Dutta & I. Mia (Eds.), *The Global Information Technology Report 2010–2011*. Geneva: World Economic Forum. Chapter 1.1, Box 3.

Korean Ministry of Knowledge Economy (2010). Analysis of Technology Transfer. Seoul: Korean Ministry of Knowledge Economy.

Kuramoto, J., & Torero, M. (2009). Public–Private Research, Development, and Innovation in Peru. In M. Graham & J. Woo (Eds.), Fuelling Economic Growth: *The Role of Public–Private Sector Research in Development* (pp. 105-158). Ottawa: Practical Action Publishing/International Development Research Centre.

Lach, S. & Schankerman, M. (2008). Incentives and Invention in Universities. *The RAND Journal of Economics, 39*(2), 403-433.

Larsen, M.T. (2011). The Implications of Academic Enterprise for Public Science: An Overview of the Empirical Evidence. *Research Policy, 40*(1), 6-19.

Lissoni, F., Llerena, P., McKelvey, M. & Sanditov, B. (2008). Academic Patenting in Europe: New Evidence from the KEINS Database. *Research Evaluation, 1*6(2), 87–102.

Litan, R.E., Mitchell, L. & Reedy, E.J. (2008). Commercializing University Innovations: Alternative Approaches. In A.B. Jaffe, J. Lerner & S. Stern (Eds.), *Innovation Policy and the Economy* (Vol. 8). Cambridge, MA: MIT Press, pp. 31-57.

Luan, C., Zhou, C. & Liu, A. (2010). Patent Strategy in Chinese Universities: A Comparative Perspective. *Scientometrics, 84*(1), 53-63.

Luintel, K. B., & Khan, M. (2011). Basic, applied and experimental knowledge and productivity: Further evidence. *Economics Letters*, 111(1), 71-74.

MacDonald, L., Capart, G., Bohlander, B., Cordonnier, M., Jonsson, L., Kaiser, L., Lack, J., Mack, J., Matacotta, C., Schwing, T., Sueur, T., van Grevenstein, P., van den Bos, L. & Vonortas, N.S. (2004). Management of Intellectual Property in Publicly-Funded Research Organisations: *Towards European Guidelines, Expert Group Report to the European Commission*. Luxembourg: European Communities.

Mansfield, E. (1998). Academic Research and Industrial Innovation: An Update of Empirical Findings. *Research Policy, 26*(7-8), 773-776.

Merrill, S.A. & Mazza, A.-M. (2010). Managing University Intellectual Property in the Public Interest *National Research Council: Committee on Management of University Intellectual Property: Lessons from a Generation of Experience*. Washington, D.C.: National Academy of Sciences.

Montobbio, F. (2009). Intellectual Property Rights and Knowledge Transfer from Public Research to Industry in the US and Europe: Which Lessons for Innovation Systems in Developing Countries? *The Economics of Intellectual Property: Suggestions for Further Research in Developing Countries and Countries with Economies in Transition.* Geneva: World Intellectual Property Organization.

Mowery, D.C., Nelson, R.R., Sampat, B.N. & Ziedonis, A.A. (2001). The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980. *Research Policy, 30*(1), 99-119.

Mowery, D.C., Nelson, R.R., Sampat, B.N. & Ziedonis, A.A. (2004). *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After Bayh-Dole.* Stanford: Stanford University Press.

Murray, F., Aghion, P., Dewatripont, M., Kolev, J. & Stern, S. (2009). Of Mice and Academics: Examining the Effect of Openness on Innovation. *National Bureau of Economic Research Working Paper Series, 14819.*

Murray, F. & Stern, S. (2007). Do Formal Intellectual Property Rights Hinder the free Flow of Scientific Knowledge?: An Empirical Test of the Anti-commons Hypothesis. *Journal of Economic Behavior & Organization, 63*(4), 648-687.

Navarro, J.C., Llisterri, J. & Zuñiga, P. (2010). The Importance of Ideas for Innovation and Productivity. In C. Pages (Ed.), *The Age of Productivity: Transforming Economies from the Bottom Up*. Washington, D.C.: Pallgrave, Macmillan.

Nelson, R.R. (2004). The Market Economy, and the Scientific Commons. *Research Policy, 33*(3), 455-471.

Nill, D.W. (2002). Corporate Sponsored Research and Development at Universities in the US. *AIPPI Journal, June 2002.*

NSF (2010). *Science and Engineering Indicators.* Arlington, VA: National Science Board.

OECD (2003). *Turning Science into Business – Patenting and Licensing at Public Research Organisations.* Paris: Organisation for Economic Co-operation and Development.

OECD (2008a). Assessing the Socio-economic Impacts of Public R&D: Recent Practices and Perspectives. *Science, Technology and Industry Outlook 2008.* Paris: Organisation for Economic Co-operation and Development.

OECD (2008b). ICT Research and Development and Innovation. *Information Technology Outlook.* Paris: Organisation for Economic Co-operation and Development.

OECD (2011). *Science, Technology and Industry Scoreboard 2011.* Paris: Organisation for Economic Co-operation and Development.

Owen-Smith, J. & Powell, W.W. (2001). To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer. *Journal of Technology Transfer, 26*(1-2), 99-114.

Owen-Smith, J. & Powell, W.W. (2003). The Expanding Role of University Patenting in the Life Sciences: Assessing the Importance of Experience and Connectivity. *Research Policy, 32*(9), 1695-1711.

PILA Network (2009). Gestión de propiedad intelectual e industrial en las instituciones de educación superior. Buenas practicas en universidades de Latinoamérica y Europa, *Research Report*: Red de Propiedad Intelectual e Industrial en Latinoamérica.

Rafferty, M. (2008). The Bayh-Dole Act and University Research and Development. *Research Policy, 37*(1), 29-40.

RedOTRI (2008). *Annual Survey on Knowledge and Technology Transfer*: Red Oficinas de Transferencia de Resultados de Investigación.

Roessner, D., Bond, J., Okubo, S., & Planting, M. (2009). The Economic Impact of Licensed Commercialized Inventions Resulting from University Research, 1996-2007, Final Report prepared for the Biotechnology Industry Organization, *www.oregonbio.org/Portals/0/docs/Education/BIO_EDU_partnership_final_report.pdf*.

Rosenberg, N. & Nelson, R.R. (1994). American Universities and Technical Advance in Industry. *Research Policy, 23*(3), 323-348.

Rothaermel, F.T., Agung, S.D. & Jiang, L. (2007). University Entrepreneurship: A Taxonomy of the Literature. *Industrial and Corporate Change, 16*(4), 691-791.

Sampat, B.N. (2006). Patenting and US Academic Research in the 20th Century: The World Before and After Bayh-Dole. *Research Policy, 35*(6), 772-789.

Sampat, B.N. (2009). Academic Patents and Access to Medicines in Developing Countries. *American Journal of Public Health, January, 99*(1), 9-17.

Sampat, B.N. (2009). The Bayh-Dole Model in Developing Countries: Reflections on the Indian Bill on Publicly Funded Intellectual Property. *UNCTAD – ICTSD Policy Brief* (5).

SCImago (2010). SIR World Report, *SCIMAGO Institution Rankings.*

Scotchmer, S. (2004). *Innovation and Incentives*. Cambridge: MIT Press.

Shane, S. (2004). *Academic Entrepreneurship.* Cheltenham: Edward Elgar.

Sibanda, M. (2007). *The State of Patenting in South Africa. Special Report 2007.*

Sibanda, M. (2009). Intellectual Property, Commercialization and Institutional Arrangements at South African Publicly Financed Research Institutions, *The Economics of Intellectual Property in South Africa.* Geneva: World Intellectual Property Organization.

So, A.D., Sampat, B.N., Rai, A.K., Cook-Deegan, R., Reichman, J.H., Weissman, R. *et al.* (2008). Is Bayh-Dole Good for Developing Countries? Lessons from the US Experience. *PLoS Biol, 6*(10), e262.

Stephan, P.E. (2010). The Economics of Science. In B.H. Hall & N. Rosenberg (Eds.), *Handbook of the Economics of Innovation* (Vol. 1). Amsterdam: North Holland, pp. 217-273.

Stokes, D.E. (1997). Pasteur's Quadrant: *Basic Science and Technological Innovation*. Washington, D.C.: Brookings Institution Press.

Thursby, J.G. & Thursby, M.C. (2007). University Licensing. *Oxford Review of Economic Policy, 23*(4), 620-639.

Thursby, J.G. & Thursby, M.C. (2011). Faculty Participation in Licensing: Implications for Research. *Research Policy, 40*(1), 20-29.

UNESCO (2010). *UNESCO Science Report 2010.* Paris: United Nations Educational, Scientific and Cultural Organization.

Van Looy, B., Callaert, J. & Debackere, K. (2006). Publication and Patent Behavior of Academic Researchers: Conflicting, Reinforcing or Merely Co-existing? *Research Policy, 35*(4), 596-608.

Van Looy, B., Landoni, P., Callaert, J., van Pottelsberghe, B., Sapsalis, E. & Debackere, K. (2011). Entrepreneurial Effectiveness of European Universities: An Empirical Assessment of Antecedents and Trade-offs. *Research Policy, 40*(4), 553-564.

Van Looy, B., Ranga, M., Callaert, J., Debackere, K. & Zimmermann, E. (2004). Combining Entrepreneurial and Scientific Performance in Academia: Towards a Compounded and Reciprocal Matthew-effect? *Research Policy, 33*(3), 425-441.

Engel, N. (2008). University Patenting and its Effects: An Assessment for Developing Countries. In C. S. Krishna (Ed.), Technology Transfer: Intellectual Property Rights Hyderabad: Amicus Books/The Icfai *University Press*, 127-142.

Vincent-Lancrin, S. (2006). What is Changing in Academic Research? Trends and Future Scenarios. *European Journal of Education, 41*(2), 169-202.

Vincett, P.S. (2010). The Economic Impacts of Academic Spin-off Companies, and Their Implications for Public Policy. *Research Policy, 39*(6), 736-747.

Wadhwa, V. (2011). Innovation's Golden Opportunity. Washington Post. Retrieved from *http://wadhwa.com/2011/06/12/washington-post-innovation%E2%80%99s-golden-opportunity/*

Walsh, J., Cho, C. & Cohen, W.M. (2005). *Patents, Material Transfers and Access to Research Inputs in Biomedical Research. Washington, D.C.: National Academy of Sciences.*

Wright, M., Clarysse, B., Mustar, P. & Lockett, A. (Eds.). (2007). *Academic Entrepreneurship in Europe.* Cheltenham: Edward Elgar.

Wu, W. (2010). Higher Education Innovation in China; Washington DC: World Bank, East Asia and Pacific Region Human Development Department.

Zucker, L.G., Darby, M.R. & Brewer, M.B. (1998). Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises. *The American Economic Review, 88*(1), 290-306.

Zuñiga, P. (2011). The State of Patenting at Research Institutions in Developing Countries: Policy Approaches and Practices. *WIPO Economics Research Working Papers, World Intellectual Property Organization.*

DATA ANNEX

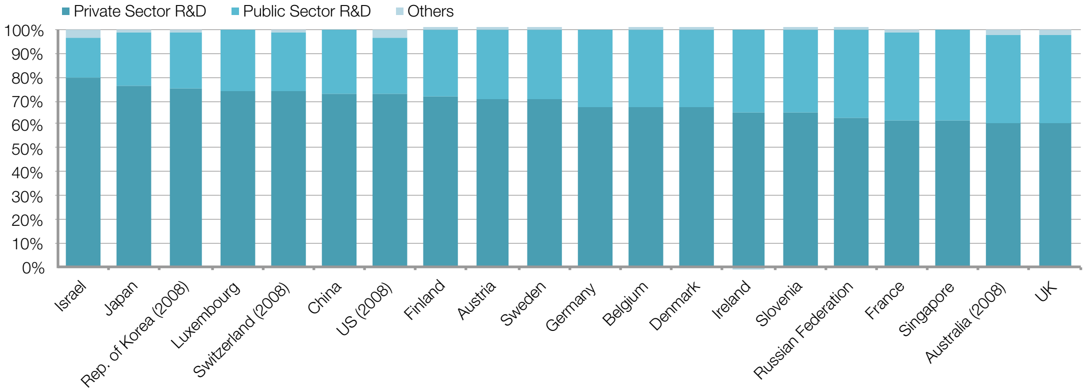
Table A.4.1: Technology transfer frameworks and legislation in selected low- and middle-income economies

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

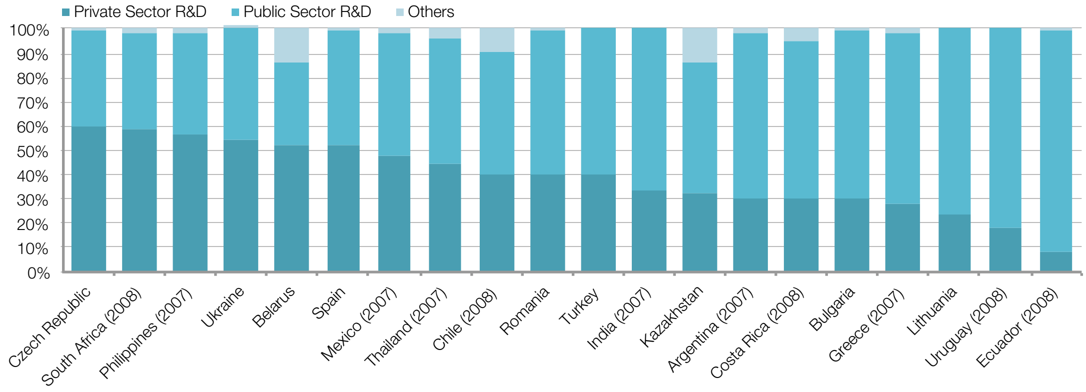
Source: Zuñiga (2011) and WIPO.

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

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



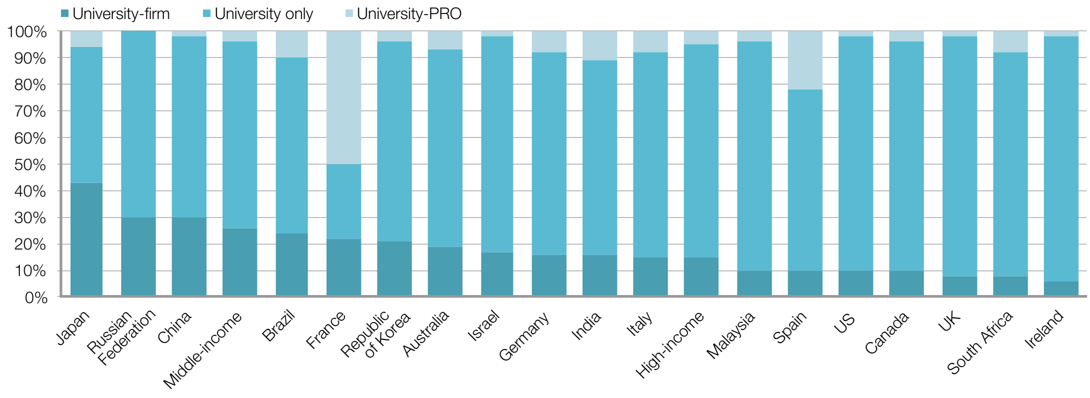
Share of public sector in total R&D in middle-income economies, in percent, 2009 or latest available year



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

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

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



Source: WIPO Statistics Database, June 2011.

METHODOLOGICAL ANNEX

Counting university and PRO patents in filings under the PCT

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

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

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

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

Counting university and PRO patents in national patent filings

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

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

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

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

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

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

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

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

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

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

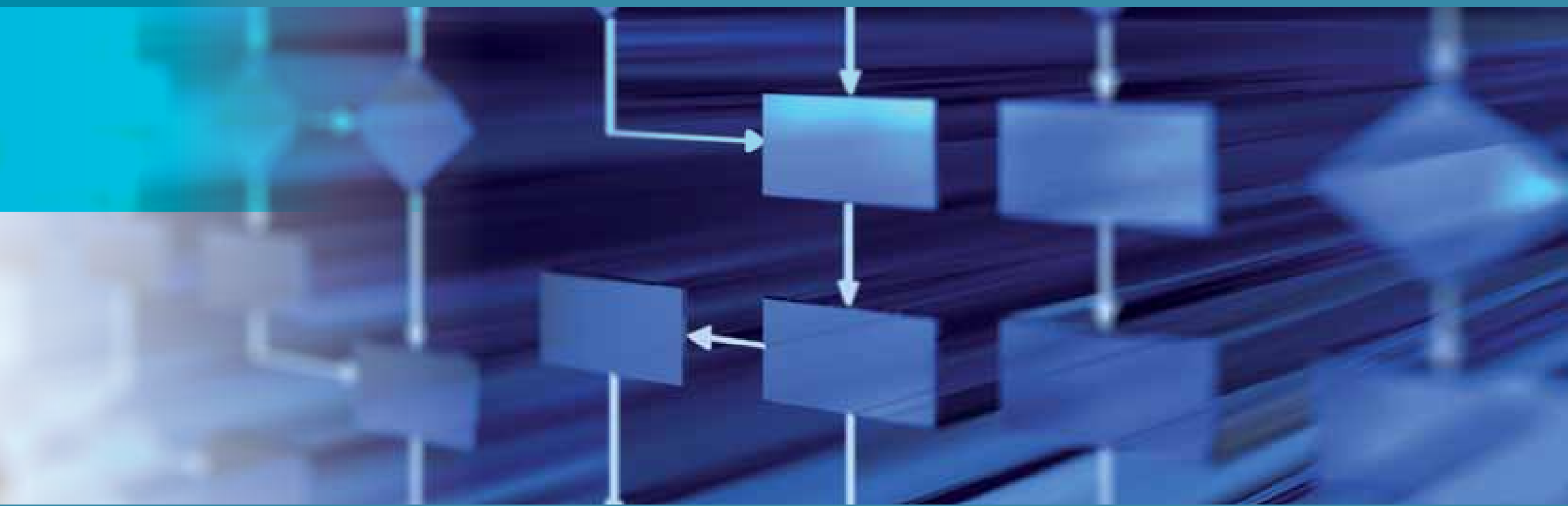
142 Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Czech Republic, Denmark, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia,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

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

ACRONYMS

ASTP Association of European Science and Technology Transfer Professionals
AUTM Association of University Technology Managers
BRICS Brazil, the Russian Federation, India, China and South Africa
CATI Cooperative Agreement and Technology Indicators
CDIP WIPO Committee on Development and Intellectual Property
CERN European Organization for Nuclear Research
CHF Swiss Franc
CIS Community Innovation Survey
CORE Cooperative Research
CPI Consumer Price Index
CSIR Council of Scientific and Industrial Research
DVD Digital Video Disc
EHCI Enhanced Host Controller Interface
EPO European Patent Office
EU European Union
EUR Euro
FDI Foreign Direct Investment
FT Financial Times
FTC Federal Trade Commission
GBP Great Britain Pounds
GDP Gross Domestic Product
GERD Gross Domestic Expenditure on R&D
GPT(s) General Purpose Technology(ies)
HIV/AIDS Human Immunodeficiency Virus/ Acquired Immune Deficiency Syndrome
ICT(s) Information and Communications Technology(ies)
IDRC International Development Research Centre
IMF International Monetary Fund
INPI Institut national de la propriété industrielle
IP Intellectual property
IPTTO Intellectual Property and Technology Transfer Offices
IRS Internal Revenue Services
ISIC International Standard Industrial Classification
JEDEC Joint Electron Device Engineering Council
JPO Japan Patent Office
JPY Japanese Yen
KIBS Knowledge-Intensive Business Services
KTI Knowledge- and Technology-Intensive Industries
LDCs Least Developed Countries
MERIT UNU Maastricht Economic and Social Research Institute on Innovation and Technology
MNEs Multinational Enterprises
MPEG Motion Picture Experts Group
MSTI Main Science and Technology Indicators
NACE Statistical Classification of Economic Activities in the European Community
NCRPA National Cooperative Research and Production Act
NESTI National Experts in Science and Technology Innovation
NIH National Institute of Health
NOTAP National Office for Technology Acquisition and Promotion
NPEs Non-Practicing Entities
NSB National Statistics Bureau of China
NSF National Science Foundation
NSRC National Survey Research Center
OECD Organization for Economic Co-operation and Development
OMPIC Office Marocain de la Propriété Industrielle et Commerciale
PATSTAT Worldwide Patent Statistical Database
PCT Patent Cooperation Treaty
PILA Propiedad Intelectual e Industrial en Latinoamérica
PIPRA Public Intellectual Property Resource for Agriculture
PPP Purchasing Power Parity
PRO(s) Public Research Organization(s)
R&D Research and development
RedOTRI Red de Oficinas de Transferencia de Resultados de Investigación
RIETI Research Institute of Economics, Trade and Industry

RLF	Royalties and License Fees
S&T	Science and Technology
SCP	Standing Committee on the Law of Patents
SDRAM	Synchronous Dynamic Random Access Memory
SMEs	Small and Medium-Sized Enterprises
SSO(s)	Standard Setting Organization(s)
STATT	Statistics Access for Technology Transfer
TRIPS	Trade-Related Aspects of Intellectual Property Rights
TTO(s)	Technology Transfer Office(s)
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
US	United States
USB	Universal Serial Bus
USD	United States Dollars
USPTO	United States Patent and Trademark Office
WIPO	World Intellectual Property Organization



For more information contact
WIPO at www.wipo.int

World Intellectual Property Organization
34, chemin des Colombettes
P.O. Box 18
CH-1211 Geneva 20
Switzerland

Telephone:
+4122 338 91 11
Fax:
+4122 733 54 28

WIPO Publication No. 944E/2011

ISBN 978-92-805-2160-3