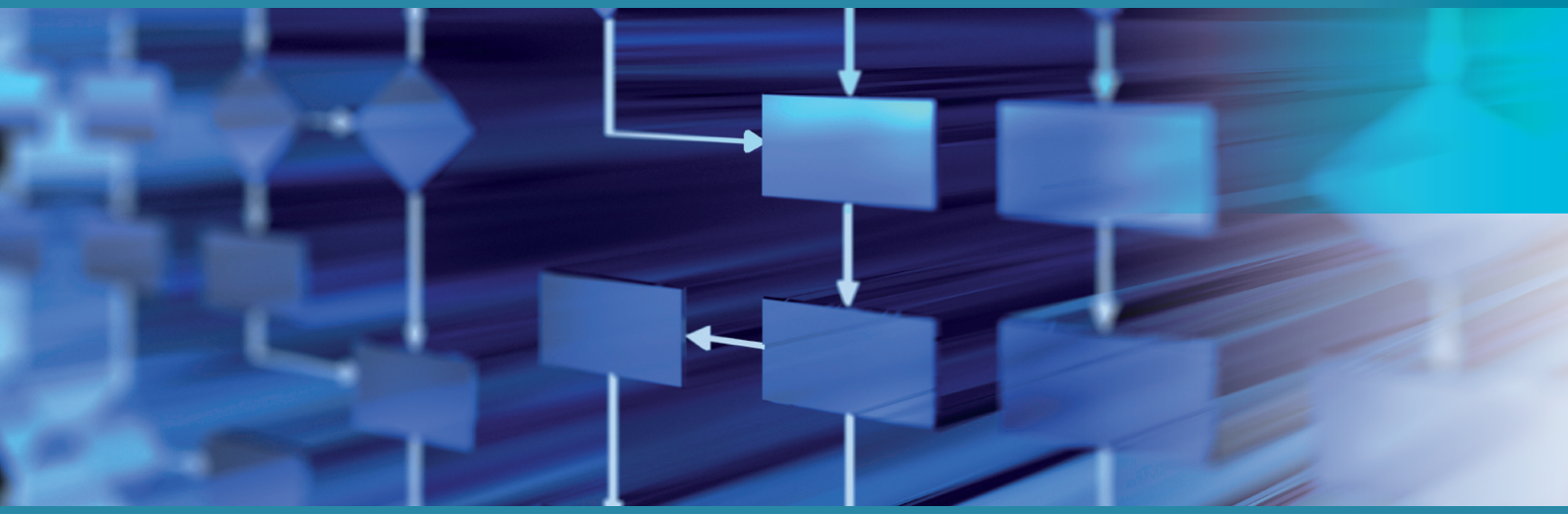

WIPO Economics & Statistics Series

2011

World Intellectual Property Report

The Changing Face of Innovation

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ORGANIZATION

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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.

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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

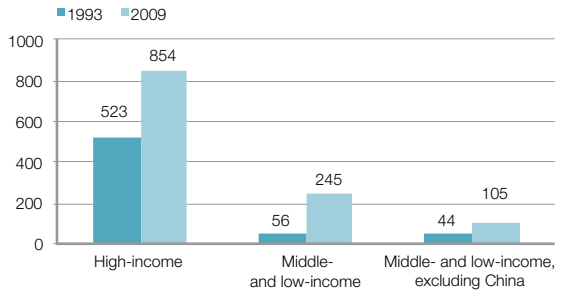
A natural first step is to look at trends in research and development (R&D). Global R&D expenditure almost doubled in real terms from 1993 to 2009. Since this period also saw marked growth of the global economy, the share of global gross domestic product (GDP) devoted to R&D increased at a more modest 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.

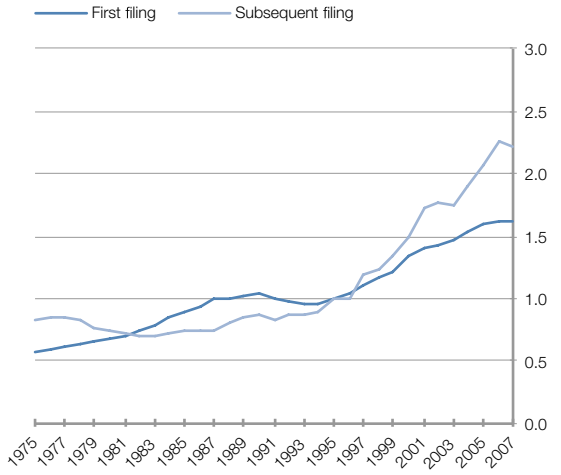
Demand for patents has risen from 800,000 applications worldwide in the early 1980s to 1.8 million in 2009. This increase has occurred in different waves, with Japan driving filing growth in the 1980s, joined by the United States (US), Europe and the Republic of Korea in the 1990s and, more recently,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

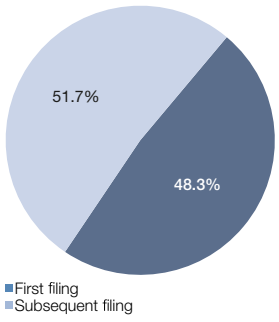
- Dividing the growth in patenting worldwide into so-called first filings – approximating new inventions – and subsequent filings – primarily filings of the same invention in additional countries – shows that the latter explains slightly more than one-half of that growth over the last 15 years (see Figure 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



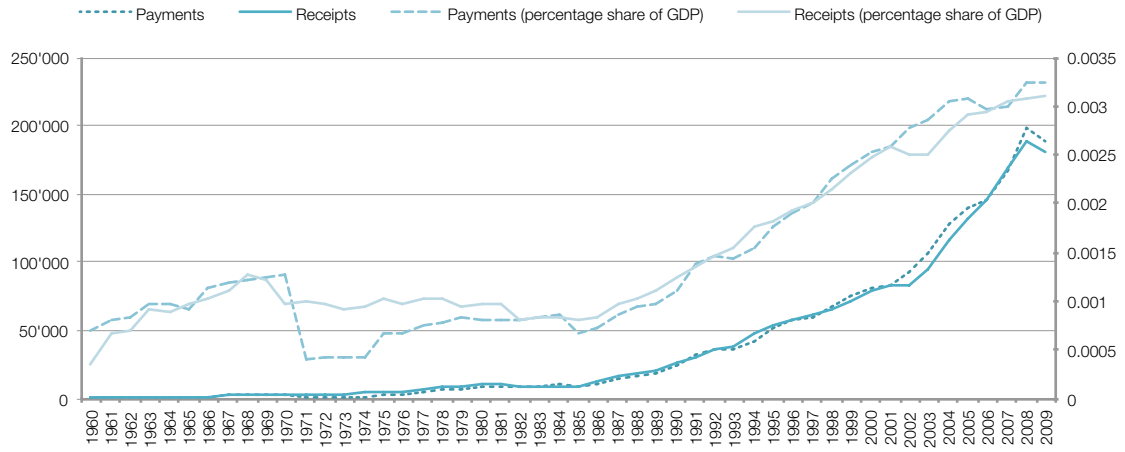
Contribution of first and subsequent applications to total growth, in percent, 1995-2007



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.

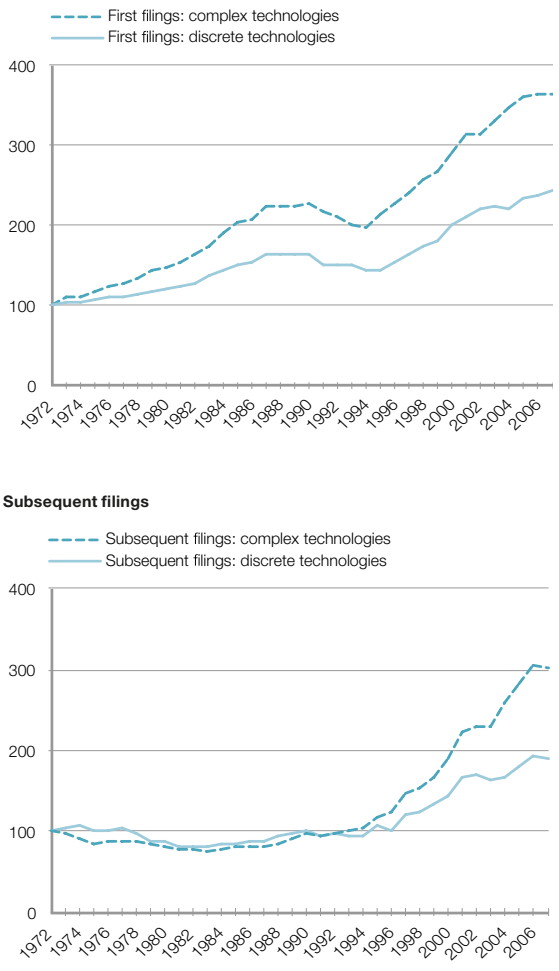
In more recent history, economists have refined their view of the IP system – partly as a result of new research and partly due to real world developments. The patent system has received particular attention.

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



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

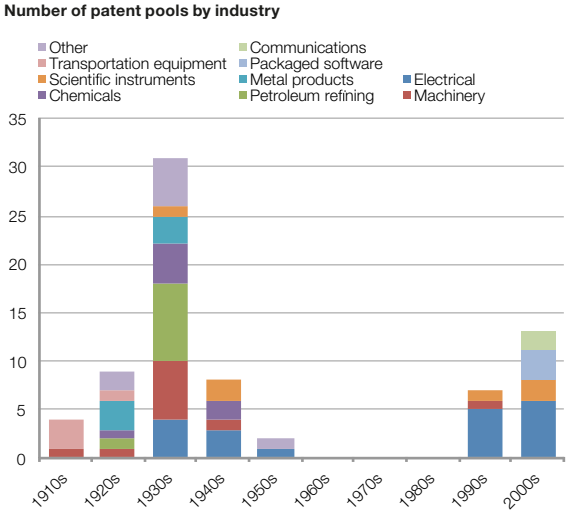
Joint IP production occurs through R&D alliances, in particular contractual partnerships and equity-based joint ventures. Data on such alliances are limited and sometimes difficult to interpret, but they suggest that firms in the ICT, biotechnology and chemical industries most frequently enter into such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



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

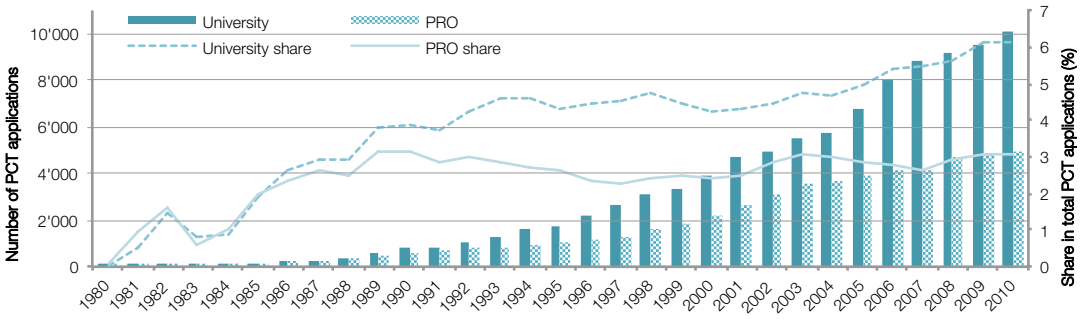
Accordingly, there has been a marked increase in patent applications by universities and PROs – both in absolute terms and as a share of total patents filed. Figure 6 depicts this trend for international patent filings under the Patent Cooperation Treaty (PCT) system.

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

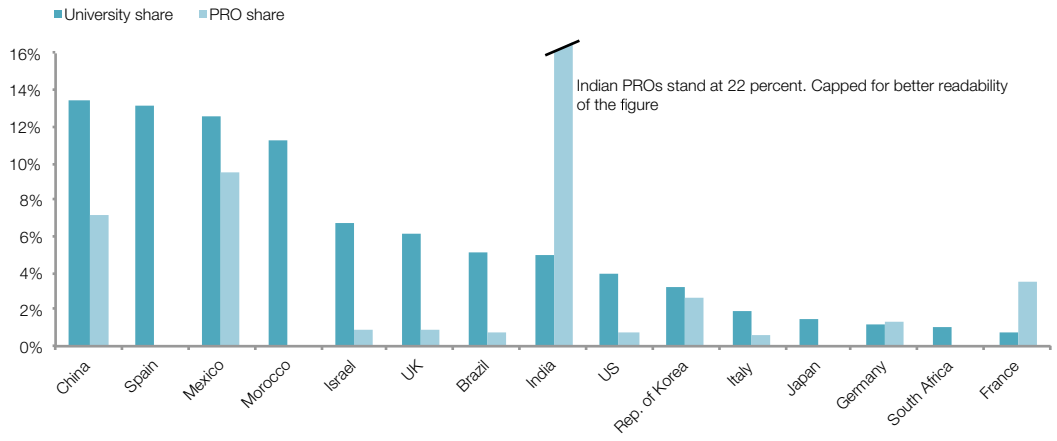
World PRO and university PCT applications, absolute numbers (left) and as a percentage of total PCT applications (right), 1980-2010



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.