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Intellectual Property and Innovation in Information and Communication Technology (ICT)

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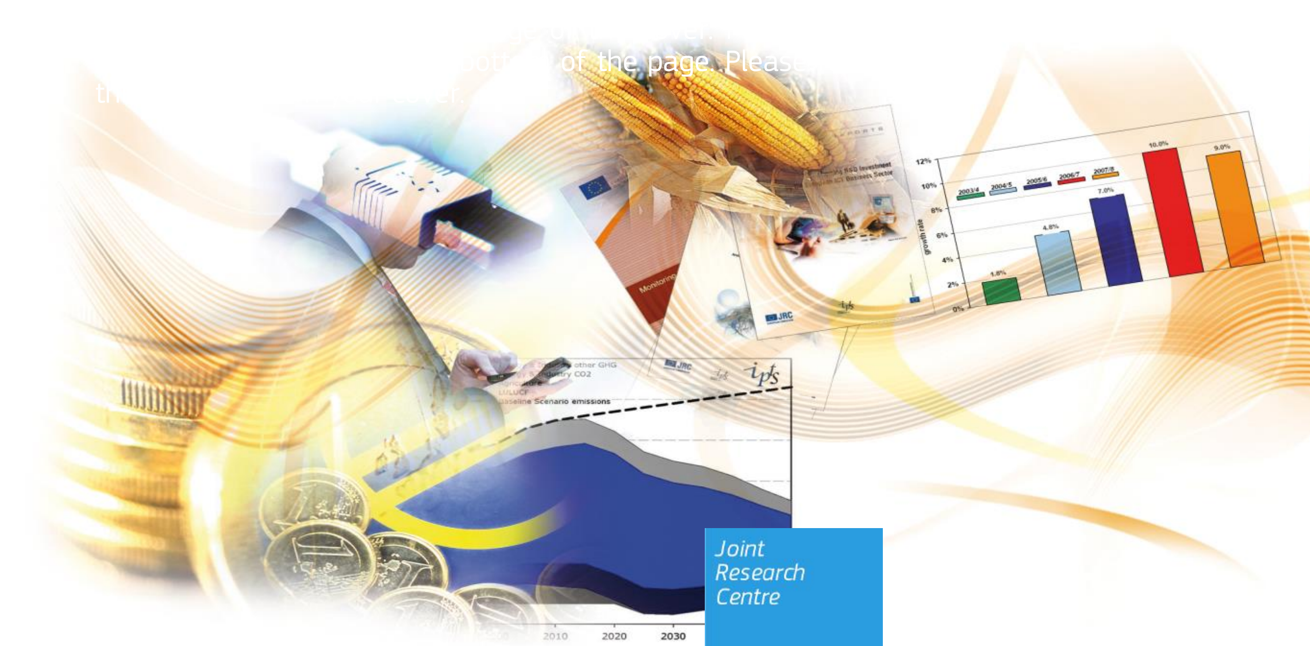

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Abstract
The aim of this study is to provide a structured review of the role of IPR in fostering innovation and economic growth in the European ICT sector. Typically IPR analysis of industries focuses on patents. In practice, however, IPR strategies are developed combining the use of different IP rights. The scope of analysis considers this and looks at the joint use of patents, trademarks and industrial designs, each protecting a different type of knowledge-based asset. Based on these characteristics, the focus of the research is to provide an overview of the mechanisms typically employed in order to appropriate the returns from R&D investments. For each formal IPR, we briefly review the main contributions to the economic literature, both theoretical and empirical, on the rationale for its existence and the effects it generates on firms' behaviour and market outcomes. We then highlight the most important emerging issues. In the final section of the study, we focus on the software industry.

Preface

This report was prepared in the context of the three-year research project on European Innovation Policies for the Digital Shift (EURIPIDIS) jointly launched in 2013 by JRC-IPTS and DG CONNECT of the European Commission. This project aims to improve understanding of innovation in the ICT sector and of ICT-enabled innovation in the rest of the economy.[1]

The purpose of the EURIPIDIS project is to provide evidence-based support to the policies, instruments and measurement needs of DG CONNECT for enhancing ICT Innovation in Europe, in the context of the Digital Single Market policy agenda and of the ICT priority of Horizon 2020. It focuses on the improvement of the transfer of best research ideas to the market.

EURIPIDIS aims are:

1. to better understand how ICT innovation works, at the level of actors such as firms, and also of the ICT "innovation system" in the EU;
2. to assess the EU's current ICT innovation performance, by attempting to measure ICT innovation in Europe and measuring the impact of existing policies and instruments (such as FP7 and Horizon 2020); and
3. to explore and suggest how policy makers could make ICT innovation in the EU work better.

The aim of this study is to provide a structured review of the role of IPR in fostering innovation and economic growth in the European ICT sector. Typically IPR analysis of industries focuses on patents. In practice, however, IPR strategies are developed combining the use of different IP rights. The scope of analysis considers this and looks at the joint use of patents, trademarks and industrial designs, each protecting a different type of knowledge-based asset. Based on these characteristics, the focus of the research is to provide an overview of the mechanisms typically employed in order to appropriate the returns from R&D investments.

[1] For more information, see the project website: http://is.jrc.ec.europa.eu/pages/ISG/EURIPIDIS/EURIPIDIS.index.html

Executive summary

Intellectual Property Right (IPR)-intensive sectors play a major role in value creation in today's economy. During the period 2008-2010, IPR-intensive industries generated nearly 26% of all jobs in the EU and contributed almost 39% of European GDP (EPO and OHIM, 2013). Companies holding formal IPRs tend to be larger and to perform better than firms that do not; in particular, IPR-holding firms are found to earn, on average, 29% higher revenues per employee and to pay 20% higher wages (OHIM, 2015).

Information and Communication Technology (ICT) industries are among the most dynamic and innovative segments of modern economies and they use IPRs intensively. ICTs represent the backbone of the Digital Single Market (DSM), the completion of which is one of ten political priorities identified by the European Commission. The digital economy opens unprecedented business opportunities but it also raises new challenges in the context of intellectual property. The IPR system needs to balance opposing goals: provide incentives to create new technologies/products and also stimulate knowledge dissemination and exchange. The definition of the right balance between incentives and dissemination is particularly challenging in ICT industries due to a series of features which characterise innovation and production in high-tech markets (short product-life cycles, cumulativeness of innovation processes, complexity of technologies, the need for standardisation and interoperability).

This report aims to provide a comprehensive and unitary analysis on the use of patents, copyright and trademarks in ICT industries. In the literature, these three protection mechanisms are usually investigated separately; to the best of our knowledge, this is one of the few studies offering a joint perspective on the use of different formal IPRs. Further research in this field is highly desirable.

The unitary perspective is useful in order to discuss the overall functioning of the current IPR system and to highlight the main challenges faced in the specific context of ICTs. In addition, the joint analysis of the various formal IPRs also allows us to identify some promising areas for future research.

IPRs in ICTs: stylised facts

- **ICT industries use IPRs intensively**. A large-scale investigation by the European Patent Office (EPO) and the Office for Harmonization in the Internal Market (OHIM) reveals that, compared to companies belonging to other industries, ICT firms use different IPRs intensively; more specifically, firms in ICT manufacturing industries are above the average in terms of their use of patents, trademarks and designs while ICT service industries, companies use trademarks and copyright intensively (EPO and OHIM, 2013). Looking at the number of patent filings, it emerges that a considerable share of worldwide applications was ICT-related. According to the OECD (2014), during the period 2009-11, ICT-patents filed under the Patent Cooperation Treaty were over 38% of the total.
- **Technological complexity combined with the cumulativeness of the innovation process leads to fragmentation of IP rights and to the emergence of patent thickets.** Evidence on the number of triple counts, a widely accepted measure for thickets, shows that patent thickets are mainly an ICT phenomenon, concentrated in several areas within electrical engineering. Even though the practical consequences of the pervasiveness of thickets are not easy to figure out, empirical contributions suggest that SMEs and companies needing to in-license technologies are the ones which are most likely to be harmed. In addition, thickets make searching for prior art more difficult, thus potentially reducing the quality of patents granted by Patent and Trademark Offices (PTOs).
- **Digital technologies make it easy to combine existing products to develop derived works.** Digital goods and software can be recombined in several different ways in order to

develop new products and services. As a matter of fact, code re-use is a common practice in software development. Similarly, with digital data, multimedia products combining different media (e.g. phones with video, or interactive sound with pictures) become possible.

- **Need for interoperability.** ICT products are affected by network effects which make interoperability among different standards crucial for the success of the technology. Interoperability enables components to communicate seamlessly and invisibly to end users, thus giving rise to significant consumer benefits.
- **Complex interaction between cumulativeness and innovation incentives.** Several theoretical contributions suggest that the role of IPRs in industries where innovation is highly cumulative is not so clear-cut. For instance, broader patents may provide more incentives to early innovators while dissuading follow-on inventors from investing in R&D (hold-up problem). Likewise, copyright protection potentially increases the cost of developing derivative works: follow-on creators may have reduced incentives to build upon existing works as they have to obtain the permission of copyright holders.
- **High litigation rates.** In ICTs, the surge in patenting is accompanied by an increase in the legal disputes concerning patent validity and infringement. US-based evidence shows that in the period 2007-2011 nearly 50% of US lawsuits involved software-related patents (GAO, 2013). Patent assertion entities (PAEs) overwhelmingly are concerned with high-tech patents; in the UK, three out of four of the companies accused of infringing a PAE patent belong to ICT industries (Helmers et al., 2013).

IPRs in ICTs: main challenges

- **Dealing with technology fragmentation and patent thickets.** Historically, the two ways that market participants have employed to cope with technology fragmentation are patent pools and standard setting organisations (SSOs). To address the thickets problem, SSOs and pools adopt IP policies regulating the licensing of the relevant patents. These policies are often very controversial: for example, many SSOs adopt the FRAND licensing and it is widely recognised that the bargaining process for the definition of fair and reasonable royalties needs to be better framed in order to increase transparency and to reach consensus on the determination the royalties. Other important issues surrounding SSOs concern the need to improve the quality of essential patents and the definition of efficient mechanisms for the governance of SSOs.
- **Market for technologies and IPR intermediaries.** A major role in dealing with the increasing fragmentation and patent thickets will be played by the market for ideas. Despite the growing importance of licensing and patent-related transactions, search costs and information asymmetries severely limit the scope for this market. In this context, patent market intermediaries and aggregators are expected to play a crucial role in stimulating IPR negotiations. PAEs are certainly the most controversial type of intermediary: they are responsible for an increasing number of patent lawsuits, but they may also significantly improve market liquidity and help SMEs to monetise the value of their IPRs. The available evidence on patent intermediaries and PAEs is US-based while little is known for Europe.
- **Transparency.** Another important issue is the need to increase transparency of the IP system. As a matter of fact, when intellectual property changes hands, there is often no record of the transaction; this generates a lack of transparency which can create uncertainty over who is in the market, what their intentions are, and whether their property is already licensed. This opacity leads potentially to more infringements, higher transaction costs, and higher costs for dispute resolutions. As regards patents, several authors and industry participants suggest that the EPO and the European Commission should explore

the feasibility of requiring the registration of patent ownership and changes in ownership. Likewise, in the realm of copyright, the Hargreaves' report argues for the creation of the Digital Copyright Exchange, a web-based market place facilitating the licensing of protected works. The simplification of pan-European licensing for copyrighted works is also one of the pillars that will support the Digital Single Market in the European Union.

- **Patent quality.** One of the main concerns related to the surge in patenting is about the quality of granted rights, where quality means the ability of a patent to "meet the statutory patentability requirements", to "leave little doubt as to its breadth", and "to disclose information that enables a person skilled in the art to implement the protected invention" (EPO, 2012a, p. 8). A decline in patent quality increases transaction and litigation costs, thus endangering the functioning of the patent system as a whole. For this reason there is a general consensus that the European patent offices should exert effort to maintain and possibly increase the quality of the patents they grant. A thorough examination process would discourage trivial or underdeveloped applications. The issue of quality is of particular concern in relation to software patents.
- **Software patents.** Patents are playing an increasingly important role in software and evidence reveals that 33% of the applications filed at the EPO in 2010 were intended to protect a computer-implemented invention (Fraunhofer/4iP, 2015). Discussions about software patentability have been very heated on both sides of the Atlantic; the high degree of abstraction of software algorithms makes it difficult to assess the patentability requirements of software applications. For this reason, opponents of software patents argue that they are inevitably of lower quality. These conclusions are mainly drawn from US patent data; further investigations on European software patents would be very welcomed.
- **New unitary patent and UPC.** The new unitary patent system (unitary patent and unified patent court) that European countries are about to adopt is expected to have a major impact on firms IP strategies and on the harmonisation process taking place in Europe. As such, the reform raises several interesting research and policy issues. The new system will coexist with the other routes companies may follow in order to apply for patent protection. How firms will react in response to this richer set of alternatives opens new and promising research prospects. Some authors observe that the reduction in patenting costs and the more effective enforcement of rights that the unitary patent system is expected to bring about might increase the number of applications with potentially negative consequences for patent quality. In addition, the new system may possibly stimulate PAEs activities.
- **Interplay between IPRs and open innovation models.** In ICTs, different innovation models and practices coexist. This coexistence has probably become most evident in the software industry. Developers use patents more and more to protect their products. At the same time, open source software is making inroads into several segments of the industry. In addition, companies often adopt hybrid business models combining open and proprietary approaches in software development and distribution. A series of legal controversies against open source vendors and users induced open source developers to adopt defensive strategies against unwarranted assertion of patents. These legal suits raise concerns about the possible coexistence of patent protected software and open source in the long-run.
- **IP bundles.** The theoretical literature suggests that firms can jointly use two or more protection mechanisms (patents, copyright and trademarks) in order to exploit both cost-driven and market-driven complementarities. This is a quite natural observation provided that different IPRs address distinct needs of companies. The joint use of IPRs is one of the most intriguing issues in ICTs where short product life-cycles, fierce competition, high product complexity require firms to use effective protection mechanisms. The empirical

literature on the use of IP bundles is extremely scant, and it is not specific to the ICT sectors. Further research is therefore needed to shed light on how firms mix different IPRs. A better understanding of the interplay of the various property rights is also important for policy makers; a policy intervention affecting one IP instruments is likely to change how firms employ the other protection mechanisms.

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1. Introduction

The aim of this study is to provide a survey of the economic literature on the role of intellectual property rights (IPRs) - patents, copyright and trademarks - in Information and Communication Technology (ICT) industries.

The term ICT refers to the set of technologies used to manage information which is anything that can be digitised. ICTs include technologies, either electronic or digital, which allow the processing, storage and transmission of information. These industrial sectors, included in the NACE classification within the “ICT manufacturing industries”, “ICT trade industries” and “ICT service industries”, are the most significant part of the Information Economy which also encompasses digital media and content industries (OECD, 2011).

ICTs are among the most dynamic and innovative segments of modern economies and represent the backbone of the Digital Single Market (DSM). The completion of the DSM is expected to entail an efficiency gain of €340 billion to the European GDP through market expansion, better services and increased employment opportunities (Pentheroudakis, 2015); the development of the DSM is one of ten political priorities identified by the European Commission. The convergence of frontier technologies ranging from wireless telecommunications to the Internet and from embedded systems to micro-electronic systems is making it possible the Internet of things, the increased connectedness of individuals and things on an unprecedented scale. In this extremely dynamic environment, it is crucial to understand how innovations can be effectively stimulated and exploited by their creators.

The cumulativeness of the innovation process, the complexity of ICT technologies and the short-life cycles typically characterising information and communication products and services are all features that make the role of intellectual property of crucial importance. At the same time, the proliferation of patent thickets, the increased number of low-quality patents being granted, as well as the emergence of patent assertion entities, particularly active in the ICT fields, raise concerns about the efficacy of the current IPR legislations. In addition, alternative uses of the intellectual property, such as that exemplified by the open source software, suggest that a more open approach might be suited to sectors where innovation is highly cumulative.

This report is organised as follows. The next two subsections present the main economic features characterising ICT industries as well as some preliminary evidence on the use of different IPRs within companies belonging to these sectors. Sections 2, 3 and 4 are respectively devoted to discussing the role of patents, copyright and trademarks in ICTs. In each section, both theoretical aspects and empirical evidence concerning each instrument are discussed. In Section 5, we concentrate on IP bundles, namely the use of different IPRs to protect the same product or technology. Section 6 is devoted to the software case. Computer programs rely heavily on both patents and copyright; however, software is also a prominent example of an industrial sector where innovation can flourish employing IPRs in a different way, to promote access, diffusion and re-use of software programs rather than to protect them against imitation. The final section of the report summarises the emerging policy implications and suggests perspectives for future research.

1.1 Main characteristics of ICT sectors

Despite their heterogeneity, ICT sectors share a common set of important economic features. In particular, ICTs are characterised by:

- **high R&D intensity and innovation rates**. Figure 1 below shows that, in the period 2006-2011, in the European Union, the share of business expenditure on R&D (BERD) in ICT industries was around 17.7% of the total. As in Europe the value added of ICT sectors is around 4% of the total value added, the figure reveals that ICTs are R&D intensive. Most of this expenditure is concentrated in the ICT-manufacturing sectors where BERD intensity (business R&D/value added) was 26.87% in 2011 compared to 3.46% for the ICT-service sectors.

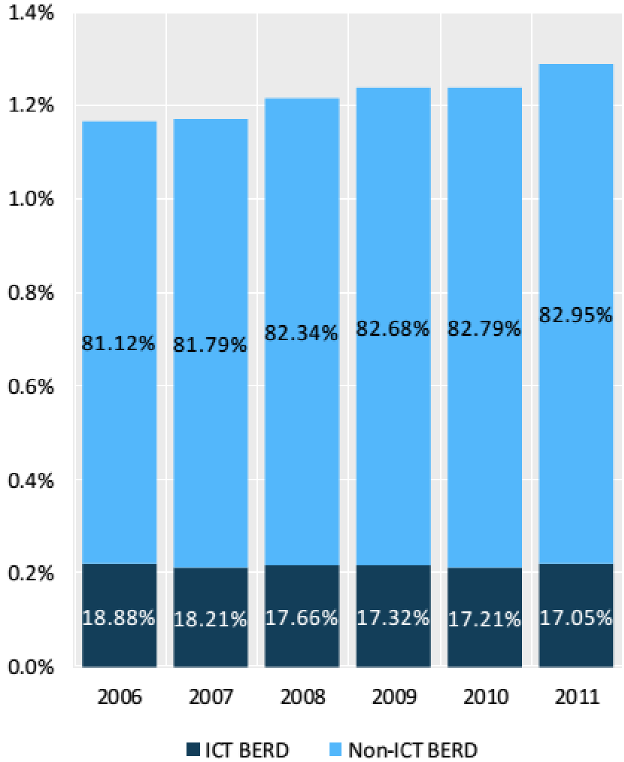

Figure 1: contribution of ICT and non-ICT BERD to total BERD intensity (BERD/GDP). European Union (2006-2011) (source: JRC, 2014)

- **cumulativeness of the innovation process**. In ICT industries, the innovation process is highly cumulative with follow-on inventions building on earlier innovations. Typically, innovation in ICT proceeds along incremental steps: inventors improve technologies developed by others or modify them to allow for new applications or uses. Take the software industry for instance. A new program often needs functionalities which are provided in existing software packages; in these cases programmers may avoid inefficient duplications by "re-using"/incorporating pieces of the already existing source code into the new program.
- **complexity of products and technologies**. Many ICT products and technologies are extremely complex since they combine several technological components. For example a mobile phone allows us not only to place calls but also to take photos, listen to music or, just like a personal digital assistant (PDA), to schedule meetings; smartphones feature advanced computing capabilities which allow high-speed Internet access. Likewise, MPEG, the well-known data compression technology, is a combination of several innovations; the basic version of MPEG is covered by a series of patents belonging to more than 20 companies and institutions ranging from the Columbia University to large corporations such as LG Electronics and Philips.
- **short product life-cycles**. ICT products are characterised by high obsolescence rates, resulting in very short life cycles. For instance, software programs become obsolete in only a few years and are replaced by new applications. In this dynamic context, most of the revenues are generated in the very short run.
- **network effects and interoperability**. ICT products are affected by network effects: the benefit an individual obtains when purchasing a product/adopting a technology increases with the number of users of the same product/technology. With network effects,

interoperability among different standards (i.e. the ability of distinct technologies to work together smoothly) plays a crucial role.

– **large economies of scale**. Typically, in ICT sectors, production is characterised by the presence of large fixed costs, on the one hand, and small variable costs, on the other. Large fixed costs may arise for different reasons; for example, the investment to deploy the physical infrastructure for telecom companies, or the cost to produce the "first copy" of a software application. Furthermore, as argue above, ICT sectors are R&D intensive, another feature which implies the importance of fixed costs over variable ones.[1]

1.2 IPRs in ICT industries

The industrial characteristics that we have briefly reviewed here above deeply affect the role of IPRs in ICT sectors. For instance, the short product life cycles typical of several high tech industries require instruments providing immediate protection to inventions. At the same time, the cumulativeness of the innovation process combined with the complexity of ICT products lead to the emergence of several different IPRs protecting the relevant technologies; as a matter of fact, as we shall see later on in this report, patent thickets are concentrated in high-tech industries.

Generally speaking, innovative firms have several instruments at their disposal in order to protect their valuable inventions; such instruments can be grouped into two broad categories: formal and informal (Hall et al. 2015). Formal instruments include patents, trademarks, industry designs and copyright; they grant innovators an exclusive - though temporary - right to use the results of their innovation efforts. According to the traditional view, this exclusivity provides firms with ex-ante incentives to invest in R&D-related activities (Hall, 2007). In other words, IPRs confer the inventor a legal right to exclude others from using the innovation, thus addressing the well-known problem of "appropriability" governing the production of knowledge (Arrow, 1962). A large scale study conducted by the Office for Harmonization in the Internal Market (OHIM) based on a survey on more than 130 thousand European firms, reveals that companies holding formal IPRs (patents, trademarks and designs) tend to be larger and perform better than firms that do not; in particular, IPR holding firms are found to have, on average, 29% higher revenues per employee and to pay 20% higher wages (OHIM, 2015). This evidence shows that there exist a positive association between IPR ownership and company performance.

Among the informal protection mechanisms, secrecy is probably the most widely used one. Lead time, namely the ability of commercialising the innovation well ahead of competitors so that substantial rents can be captured before copycats are introduced, and complexity, aimed at preventing competitors from engaging in reverse engineering or inventing-around strategies, are other forms of informal instruments commonly employed by firms. Informal instruments are related to different actions that firms can undertake in order to protect their innovations and to maximise their expected returns. In principle, informal IPRs are very cost-effective as they do not entail any application or enforcement costs. Nonetheless, they are not guaranteed by the law and do not legally protect from imitation. The importance of informal IPRs has grown significantly in the last decades also among high-tech companies. As a matter of fact, informal IPRs can be particularly appropriate to protect innovations in industries where product life-cycles are short, as in today's high-tech industries.

Typically, in order to obtain legal protection, formal IP instruments require valuable information regarding the innovation to be disclosed during the application process. Information disclosure and the greater transparency characterising formal IPRs make these instruments to be preferred to the

[1] Evans and Schmalensee (2002) provide clear evidence of the fact that production in ICT industries exhibits increasing returns to scale. According to their estimates, in 1998 material expenses (variable costs) accounted for more than 50% of revenues in manufacturing industries overall; for ICT industries this figure reduces to less than 30%.

informal ones by regulators and policy makers. In this report we focus on formal IPRs and, specifically, on patents, copyright and trademarks.

<u>The use of formal IPRs in ICTs: first evidence</u>

A joint report by EPO (European Patent Office) and OHIM provides some preliminary evidence on the use of formal IPRs in the European industrial sectors (EPO and OHIM, 2013). Specifically, the study highlights what sectors are intensive in the use of patents, trademarks, industrial designs and copyright. A sector is defined as IPR-intensive when the use of a certain instrument per employee is above average. Table 1 presents the results of the study[2] and shows that, overall, ICT firms make an intensive use of the different IPRs. Firms in ICT manufacturing industries are above the average in terms of the use of patents, trademarks and designs. By contrast, and with the exception of the firms operating in telecommunications, patents per employee are below average in ICT service industries which, on the opposite, are intensive in the use of trademarks and copyright.[3]

NACE	Description	TM	Patent	Design	Copyright
ICT manufacturing industries					
26.11	Manufacture of electronic component	X	X	X	
26.12	Manufacture of loaded electronic boards		X		
26.20	Manufacture of computers and peripheral equipment	X	X	X	
26.30	Manufacture of communication equipment	X	X	X	
26.40	Manufacture of consumer electronics	X	X	X	
26.80	Manufacture of magnetic and optical media	X	X	X	
ICT trade industries					
46.51	Wholesale of computers, computer peripheral equipment and software	X			
46.52	Wholesale of electronic and telecommunications equipment and parts	X		X	
ICT service industries					
61.10	Wired telecommunication activities				
61.20	Wireless telecommunications activities	X	X		X
61.30	Satellite telecommunications activities	X	X		
61.90	Other telecommunications activities	X	X	X	
58.21	Publishing of computer games	X			X
58.29	Other software publishing	X	X		X
62.01	Computer programming activities	X			X
62.02	Computer consultancy activities	X			X
62.03	Computer facilities management activities	X			X
62.09	Other information technology and computer service activities	X			X
63.11	Data processing, hosting and related activities	X			
63.12	Web Portals	X			X
95.1	Repair of computers and communication equipment				

Table 1: IPR-intensive industries within ICTs (source: EPO and OHIM, 2013)

The importance of different instruments in defining the IP strategy of ICT companies is confirmed by the recent study on the innovative output of the world's top Research and Development investors carried out by EC-JRC and OECD (see Dernis et al., 2015). Notably, eight out of the top ten patenting companies are ICT firms, with Samsung Electronics being the company that patented the

2 We only present the evidence for ICT industries; evidence related to other industrial sectors is in EPO and OHIM (2013).

3 The importance of IPRs for the different industrial sectors is a multifaceted phenomenon. The methodology proposed by EPO and OHIM (2013) is just one possible way of measuring it, not the unique. For instance, ICT services are found to be not intensive in the use of patents but this does not necessarily imply that such instruments are not important for companies operating in these sectors; it might be the case that the relevant technologies are covered by few, high-quality patents.

most during the period 2010-12. ICT companies are also very active in trademarking even though this occurs also in the case of other industrial sectors, e.g. Pharmaceuticals and Chemicals.

2. The role of patents in ICT industries

A patent grants a temporary monopoly for the exploitation of an invention. Patent-holders acquire, for a limited period of time, the exclusive right to prevent others from using, commercialising or importing the patented products or processes. In exchange for these rights, innovators have to disclose important information about their inventions; they have to describe the possible uses of their inventions and the information they disclose has to be detailed enough to allow an expert in the relevant technological field to replicate the invention. Among the formal IPRs, patents provide innovators with the strongest form of protection and, for this reason, the granting of patents requires a substantial screening. Patent Offices assess whether the invention satisfies a series of requirements, the most important of which are novelty, non-obviousness and industrial applicability. The whole process from the filing of the application to the final decision by the Patent Office takes time and it is expensive.[4] According to international patent laws, not all subject-matters can be patented; discoveries, scientific theories and mathematical methods are typically not eligible for patentability.

Patent applications increased steadily during the last decades. For the year 2013, WIPO (2014) estimates that the number of applications filed world-wide amounted to more than 2.5 million, up 9% from the previous year. ICT-related patents represent a notable share of this mass of applications. In the year 2012, Computer technology was the field with the highest share of patents applied word-wide (7.6% of all the applications). According to OECD (2014), during the period 2009-11, ICT-patents filed under the Patent Cooperation Treaty (PCT) were over 38% of the total. The same share was registered in the years 1999-2001 even though, in absolute terms, in ten years the number of filings had nearly doubled.[5] The United States are still the largest applicant of ICT-related patents filed under the PCT, but their share has diminished from 45% (years 1999-01) to about 25% (years 2009-11). By contrast, Japan, Korea and China are on the rise. Beijing is now the third-largest applicant of ICT-related patents with a share of about 13%.[6] A noteworthy trend is the increase in software patenting.[7] Bessen and Hunt (2007) estimated that the percentage of software patents granted by the USPTO rose from 1.1% in 1976 to 14.9% in 2002. In 2010 in Europe, Fraunhofer/4iP (2015) find that applications for computer-implemented inventions at EPO were about 44 thousand, 33% of the total. Thomson Reuters (2015) estimates a worldwide 6% year-over-year increase in telecommunication patents between 2013-14: only in mobile telephony, patents grew by 9%, from 71,091 to 77,477.

The surge in patenting has been accompanied by increasing concerns about patent quality. As we discuss below, technological complexity combined with the broadening of patent-eligible subject-matters have generated an increase in litigation and stimulated "patent wars" in ICT industries world-wide. The widespread perception is that a decline in patent quality endangers the functioning

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4 In a comprehensive study employing a random sample of more than 200 thousand applications filed at the EPO, Harhoff and Wagner (2009) find that the patenting process (duration from filing date and the final decision of the EPO/withdrawal of the applicant) lasts 4.331 years on average.

5 The increase in ICT-related patents is a long-run phenomenon. According to Hall et al. (2001) in the early 80s the number of applications filed at the USPTO in the field of "Computer and Communication Technology" represented just 5% of the total; by the late 90s this number increased to 20%.

6 Eberhardt et al. (2011) analyse the characteristics of the recent explosion of patent filings by Chinese firms. They show that Chinese applications are filed by a very small group of ICT companies.

7 Although Patent Offices classify patents by technology classes, they do not distinguish whether the invention is based on software or on some other underlying technology. For this reason, in order to measure the extent of software patents, researchers need to implement their own algorithms typically based on keywords search.

of the patent system as a whole. These concerns are related especially to the patenting process at the USPTO (Jaffe and Lerner, 2004) but have started being discussed also in Europe (EPO, 2012a). Even though there is no an agreed upon definition, a patent of high quality "satisfies the statutory patentability requirements, leaves little doubt as to its breadth, and discloses information that enables a person skilled in the art to implement the protected invention" (EPO, 2012a, p. 8).

Unitary Patent and Unitary Patent Court

In Europe applicants can follow two routes in order to obtain patent protection for their inventions. They can either file an application at the national level, through a national patent office, or they can apply at the EPO. In this latter case, a single application entitles the innovator to obtain protection in 38 European states. More specifically, once the EPO grants a patent, the innovator has the option to choose in which European country to validate it; validation, publication and renewal procedures are then administrated locally by the national patent offices where the patent has been validated. Also enforcement occurs locally through the national patent courts. For these reasons the "EPO route" does not offer a pan-European patent but, rather, it provides a bundle of national patents (Europe Economics, 2014).

On 17 December 2012 the Council of the European Union approved two regulations that create a European patent with unitary effect, the "unitary patent". This reform is considered one of the most radical changes in European patent practice in over 40 years; it will create a new unitary patent (UP) right and a unified patent court (UPC) system across Europe.

Under the new legislation, a unitary patent, once granted by the EPO, will provide uniform protection in all of the participating countries. The UPC will be responsible for rulings in disputes regarding infringement or validity of a unitary patent; rulings will apply across the whole territory of the patent. Unitary patents will be subject to the payment of a single set of renewal fees to the EPO. Entry into force is expected to occur when member states have ratified the UPC agreement. The unitary patent system will not replace the current system based on patents granted by the EPO and validated in individual countries, even though these national patents will be subject to the jurisdiction of the UPC instead of being subject to national courts. On top of this, applicants will continue to have the possibility to obtain national patents issued by national patent offices.

The main benefits of the new UP system are highlighted in IPO (2014). A unitary patent will not need to be validated in each individual member state. As such, the unitary patent will tend to offer a lower cost alternative to obtaining and maintaining a bundle of rights. By not requiring translations into a language of each contracting state, and by requiring the payment of only a single renewal fee for the group of contracting states, the unitary patent aims to be cheaper than current European patents.

As stressed in IPO (2014), the unitary patent offers savings also for enforcement. Patentees will only need to enforce their patents in one court, rather than in multiple national courts, avoiding duplicated litigation. Moreover, a unitary patent will be subject to a single legislation, as opposed to those of multiple countries. This is expected to increase legal certainty, to speed-up decisions in litigation cases and, hence, to reduce attorneys costs.

One of the main issues related with the new UP/UPC system regards how the new system would impact on patenting activity of potential users, namely on their decisions of whether and where to file, validate and renew a patent as well as on their enforcement strategy. Europe Economics (2014) review the quite rich literature developed in the area of cost and value of patenting and of patent litigation in recent years and uses the findings of this literature to obtain predictions on the likely impact of the new UP/UPC regime. Europe Economics (2014) categorises benefits and costs for each of the various patenting phases on which the new UP/UPC regime might have an impact: validation/registration, renewal and infringement litigation. As regard validation/registration the main benefits are related to the reductions in translation costs, in the lower legal fees for validation and/or patent transfer activity and in the smaller administrative costs. According to Europe Economics (2014) the new system will not have any direct costs in this area. As the renewal phase is concerned, the "Select Committee of the Administrative Council" of the EPO has recently agreed to set renewal fees for unitary patents equal to the sum of the fees in Germany, UK, France and the Netherlands, namely the four countries where patents are most frequently validated (the "true top-4" proposal). The new centralised system may generate costs related to its lack of flexibility, as it will be impossible to let a patent lapse in some jurisdictions while keeping it alive in others. As regard the infringement/litigation phase, substantial savings in legal costs are expected to arise as the new system is centralised and the whole process less uncertain. Potential costs may eventually be due to the fact that legal representatives acting before the UPC will tend be more expensive as they need to be more qualified.

To assess empirically the validity of these predictions, Europe Economics submitted a questionnaire to a random sample companies that had filed at least one patent application at EPO in 2012. A total of 439 firms completed the survey, classified into four clusters: pharmaceuticals, electronics (essentially, ICT firms), biotechnology and SMEs/universities. Interestingly, the authors find that the UP is expected to deliver an overall benefit to patent users from all clusters, with benefits outweighing costs. As regard the benefits of the UPC, the authors find that firms in the electronics/ICT cluster perceive the impact of the unitary patent court as less important than the firms in the other clusters. A more recent survey, finds that 91% of telecoms, media and technology companies expect important benefits from the unitary patent system thanks to the harmonisation in IP enforcement, the increased legal certainty, and the more efficient management patent portfolios (Allen and Overy, 2014).

There is a general consensus about the benefits of the new regime in terms of lowering patenting and litigation costs. In addition, as long as the current routes for patent applications coexist with the UP/UPC regime, companies will have new strategic options at their disposal in order to protect more effectively their inventions. As stressed in Pentheroudakis (2015), the impact of the new system on companies will depend on their characteristics in terms of the business model they adopt, the size of their patent portfolios as well as on the specificities of the industrial sectors in which they operate. Therefore, how firms will react in response to this richer set of alternatives opens new and promising research prospects. Nonetheless, some authors observe that the reduction in patenting and litigation costs may also have adverse effects and stimulate the strategic use of patents. The debate is about whether the UP/UPC regime will encourage the activity of the patent assertion entities (PAEs). This is a critical issue that we will discuss below.

2.1. Basic economics of patents

In a textbook-style representation, innovation is typically described as a discrete event that takes place once and for all; an isolated event, unrelated to any past or future invention. Although useful in order to focus on the basic trade-off between incentives to innovate and deadweight loss and to clarify the basic role of patents, this approach does not capture several critical features characterising innovation in frontier industries. As argued in Section 1, cumulativeness and complexity are two important features characterising the innovation process in ICTs. In these sectors, the role of patents, and, more generally, of IPRs is less clear-cut than in the standard, isolated event, scenario. For instance, a broadening of the scope of protection may have differentiated effects on the different generations of inventors involved in the innovation process: it may benefit early inventors while harming follow-on innovators who need to access the protected technologies. The overall effect of the policy on innovation might go either way provided that it encourages early R&D activities but it may reduce the incentives of future innovators. More specifically, in order to understand the role of patents in the ICT sectors one needs to consider several additional welfare effects beyond the traditional trade-off between R&D incentives and deadweight loss.

When innovation is cumulative, early inventions are extremely valuable: they pave the way for follow-on innovators, thus generating positive externalities. In other words, early inventions create the basis for further technological improvements, and, therefore, their social value is not only related to the utility generated from their use but also to the contribution they provide to future innovations.[8] At the same time, patent protection on pioneer innovations may undermine the R&D incentives of follow-on inventors. The risk of being involved in lengthy and costly patent litigations, or simply the licensing fees due to the owners of the relevant patents may severely reduce the incentives to invest in research activities of follow-on inventors. This is to say that, with cumulative innovation, strict patent protection may hold future innovations up. Clearly, the "hold-up" problem is more likely to emerge as the mass of existing patents and patent applications enlarges. Moreover, hold-up is exacerbated when Courts are keen on issuing injunctions against the alleged patent infringers.[9]

Also the role of imitation needs to be reconsidered when innovation is sequential. With isolated inventions, imitation reduces the innovator's profits and, therefore, it certainly diminishes R&D incentives. However, Bessen and Maskin (2009) argue that when innovation is cumulative, imitation may have the opposite effect. As a matter of fact, imitation affects firm's profitability in two ways. In the short-run, imitators compete with innovators, thus reducing their profits. However, in the longer run, innovators may, in turn, imitate future inventions developed by competitors, therefore providing consumers with more innovative and technologically more advanced products. This second, long-run, effect increases the incentives to innovate. According to Bessen and Maskin (2009), there are good reasons to believe that in highly dynamic industries such as software, personal computers and semiconductors, the long-run effect dominates the short-run one and innovation may be fostered by the possibility of imitation. In other words, in such industries innovation would flourish with weak patent protection.

Another aspect makes the role of patents less clear-cut: in ICT industries, patents act not only sequentially but also in clusters, the patent thickets (Encoaua and Madiès, 2014). In order to innovate, follow-on inventors need to access a series of independent patents reading on the relevant technology. This occurs in many high-tech industries where products incorporate complex technologies and often require the use of several patented components all of them, even minor ones, being essential for production. With a highly fragmented property of the relevant technologies licensing fees may increase exponentially due to the complements problem (also known as royalty stacking).

2.2 Empirical evidence and the "Patent paradox"

As seen above, even though the increase in patenting is common to many sectors, it is particularly marked in high-tech industries.[10] This surge in the number of patents seems to be at odds with what found by Cohen et al. (2000) in an investigation based on a detailed survey questionnaire administered to 1,478 R&D labs in the US manufacturing sectors. The authors find that firms

[8] Scotchmer (2004) presents a thorough discussion on the cumulative nature of the innovation process. In order to emphasise the role of externalities, and to highlight the fact that in some sectors the fortunes of follow-on innovators are, to a large extent, attributable to earlier inventors, Scotchmer reports a famous quote by Sir Isaac Newton. Commenting his great achievements in physics and mathematics, Newton said "If I have seen further it is by standing on the shoulders of giants".

[9] An issue that has received little attention in the literature is the "reverse hold-up" (or hold-out) according to which patent holders would be under-compensated. As reported by Geradin (2010) this occurs especially with FRAND licensing where implementers of standardised technologies have strong incentives to infringe standard essential patents provided that in the worst scenario Courts will obligate them to pay small licenses (those implied by FRAND terms).

[10] From the last annual report of the EPO, the majority of the top applicants work in the electronics and IT sectors, with Samsung heading the ranking in 2014 (see EPO, 2015a)

consider patents as the second to last mechanism in terms of its effectiveness in protecting innovations; lead time and secrecy emerge as the most effective protection instruments at firms' disposal. These findings are confirmed by Graham et al. (2010) in a survey on 1,332 US high-tech start-ups active in biotech, medical devices, software and IT hardware (semiconductors, communications and computer hardware). According to the authors, technology entrepreneurs report that the patent system is neither working particularly poorly nor well for their companies and industries. Interestingly, software companies consider patents as the least important mechanism to appropriate the returns of their R&D efforts.[11] These contrasting figures, surge in patenting and little effectiveness of patents as an appropriation mechanism, gave rise to what has been dubbed as the "patent paradox".

This paradox can be explained by considering the changing role that patents have in modern economies. In ICTs as well as in other industrial sectors with complex technologies, patents are used as "bargaining chips" in order to improve the outcomes of licensing/cross-licensing negotiations (Hall and Ziedonis, 2001). Similarly, large patent portfolios may represent an important defensive safeguard against the possibility of rival firms taking legal actions for patent infringement, or they can be used aggressively in order to foreclose competitors. Also Torrisi et al. (2014) confirm the importance of strategic motives for patenting. They use survey data on inventors in 23 countries (European countries, Israel, the United States and Japan) filing applications at the EPO between 2003 and 2005. The authors show that a substantial share of patents is not being used by firms internally or for market transactions and they interpret this evidence as a support to the importance of strategic patenting. They also find significant differences across industrial sectors, with patents in complex technologies (such as ICTs) which are more likely to be employed strategically than in other technological areas. On top of strategic uses, the empirical literature has shown that patents are also employed for signalling purposes (Graham et al., 2010). For instance, several studies show that possessing a large stock of patents increases the chances of start-ups and SMEs of being financed by venture capitalists (Cockburn and MacGarvie, 2009).

Looking at software, Bessen and Hunt (2007) argue that the tremendous rise in patenting is mainly related to strategic motives. Table 2 shows the distribution by industry of software patents granted by the USPTO. It emerges that three out of four software patents belong to firms operating in some manufacturing industries (28% in electronics and 24% in machinery); software publishers, in principle the companies mostly involved in the development of software programs, account for only 5% of the overall number of software patents. By contrast, the share of programmers and engineers, i.e. those involved in the writing of software code, is much larger in software publishers and in non-manufacturing sectors. Only 11% of the overall programmers and 32% of the total number of programmers and engineers are employed in the manufacturing sector. These figures suggest that there is little correspondence between the R&D activity aimed at developing new software and patent ownership.

[11] Graham et al. (2010) find that patents are the most important appropriation mechanism for biotech firms and they are an important tool for firms producing medical devices and for venture backed hardware companies.

	Software Patents (a)	Programmers (b)	Programmers and Engineers (c)
Manufacturing	**75%**	**11%**	**32%**
Chemicals	5%	1%	2%
Machinery	24%	3%	7%
Electronics	28%	2%	7%
Instruments	9%	1%	4%
Non-manufacturing	**25%**	**89%**	**68%**
Software publishers and other software	7%	33%	18%

Table 2: the distribution of software patents in the US (Source: Bessen and Hunt, 2007)

2.3 Patent thickets

In ICT industrial sectors the combination of complex technologies and high patenting volumes favours the emergence of the patent thickets, defined as a "dense web of overlapping intellectual property rights that a company must hack its way through in order to actually commercialize new technology" (Shapiro, 2001). As discussed in EPO (2012b), a patent thicket usually involves multiple patents on the same, or similar technologies, held by different parties.

According to Hall et al. (2013) there are several leading explanations to the emergence of patent thickets. Some of them are specific to the US, where this phenomenon has been first identified, while others apply world-wide. Among the main drivers explaining the surge in patent thickets there are:

1. the strengthening of patent rights combined with the broadening of patentable subject matters during the 1980s;
2. the cumulativeness of the innovation process together with the increasing complexity of technologies;
3. the increasing role of strategic patenting and the rise of patent assertion entities (PAEs), namely companies who enforce patent rights against accused infringers in an attempt to collect licensing fees, without being involved in production;
4. the lack of resources and distorted incentives in Patent Offices faced with a flood of patent applications;
5. the growing importance of high-tech products and the rise in the demand for patents worldwide.

Following Shapiro (2001), the literature suggests that patent thickets may have unattractive economic consequences. The standard monopoly dead-weight-loss associated with patent protection is likely to be amplified by the complements problem/royalty stacking: the uncoordinated setting of licensing fees by the different patent holders which may lead to multiple marginalisations, thus increasing market prices and discouraging the use of these products/technologies. Producer returns are reduced due to these marginalisations and this may go to the detriment of new product design and development. In the more severe cases, the prospect of paying large patenting fees may discourage entry and prevent production altogether.[12]

[12] In a well-known study on biomedical research published in 1998 in *Science*, Michael Heller and Rebecca Eisenberg (see Heller and Eisenberg, 1998) argue that royalty stacking may lead to the *tragedy of the anti-commons:* when the property of the relevant technologies is highly fragmented, time and resources needed to complete all the licensing agreements may exponentially increase with the size of the patent thicket; as a result, access to the technology may be delayed, or even prevented and the innovation process may considerably be slowed down.

On top of these unattractive consequences, patent thickets also generate uncertainty about the validity and scope of property rights and increase search costs (EPO, 2012b). The proliferation of patent applications has dramatically increased the backlog of Patent Offices thus lengthening the period of pendency, i.e. the time between the filing of the application and the final decision. Figure 2 shows the distribution of pendency times at the EPO and at the USPTO in the periods 2000-02 and 2010-12. As it is evident, pendency is a relevant phenomenon on both sides of the Atlantic but it appears to be particularly problematic in the US, where pendency rates have unambiguously increased in the last years. Long pendency rates are costly for applicants as pendency delays the time of granting a patent which can be used to protect an invention in the market, to raise funding, or to collect licensing revenues. Pendency has also an important impact on non-applicants as excessive delays may increase uncertainty over the technology they can use if pending applications cover part of the technology space in which they are active (IPO, 2013).

Moreover, this backlog may lead to a serious decrease in patent quality. Many scholars have argued that the USPTO is issuing a significant number of low-quality patents, which do not meet the novelty and non-obviousness requirements (see, Jaffe and Lerner, 2004). As a result of this, uncertainty regarding patent's validity is severely exacerbated with potentially negative consequences on firm innovation activities. Although less compelling, these concerns appear to be relevant also for the EPO (see London Economics 2010).

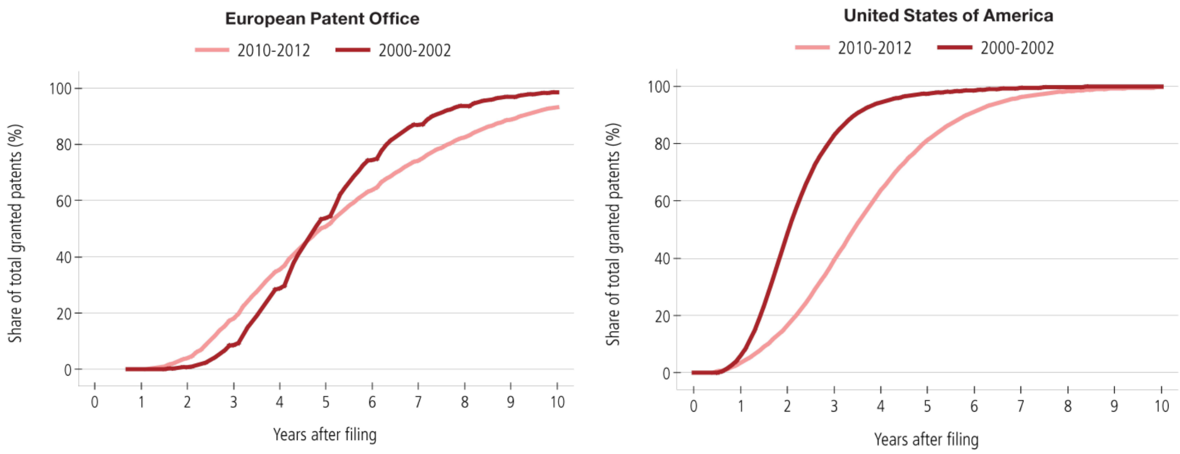

Figure 2: pendency in Europe and in the US
(source: WIPO statistic database and EPO PATSTAT, October 2014)

Patent thickets combined with a broadening of the patentable subject matters may increase search costs and uncertainty also due to other reasons. Applicants as well as Patent Offices may not be aware of all the relevant prior art, hence granted patents may turn out to be of low quality, that is to have a too broad scope or, in the most extreme cases, they may fail to meet the patentability requirements. As observed by Cockburn and MacGarvie (2009) in a study on software patents in the US, the lack of experience of examiners in the new subject matters and the blurred boundaries of granted patents dramatically increase the uncertainty about the existing prior art as well as the possibility of being sued. Uncertainty about the validity of software patents is confirmed by Bessen and Meurer (2008); the two authors find that the probability of software patents to be appealed to the Federal Circuit is two times higher than that of other patents, a clear evidence supporting the concerns about the validity and the boundaries of the software patents issued by the USPTO.

On the same lines of Bessen and Meurer, EPO (2012b) points out how uncertainty about the extent of validity of patents represents one of the reasons why during the last years there has been a significant increase in patent litigation, another potentially negative consequence of patent thickets.

Measuring patent thickets

An issue that has attracted the attention of economists is how to quantify the extent of patent thickets. Several measures have been proposed and applied in the economic literature (see, among others, Noel and Shankerman, 2013 or Galasso and Shankerman, 2010). These measures approximate the extension of thickets by using the number of patent applications filed in a given technological field or by using a combination of other indicators such as concentration indexes, oppositions at EPO, citations, patent family size, etc. These approaches are not entirely satisfactory as they do not capture the very basic nature of a thicket, that is of being "a dense web of overlapping patent rights".

To address this limitation, Graevenitz et al. (2011) propose another methodology where patent thickets are identified on the basis of mutual blocking relationships among firms. Mutual blocking occurs if, for example, firm A owns technology that prevents firm B from pursuing its research without infringing on A's patents, and vice-versa. The authors introduce the concept of "triple" to identify patent thickets; a triple is a group of three firms in which each firm is in a blocking relationship with the other two.

Applying this methodology to EPO applications, Hall et al. (2013) find that the growth rates in triples counts are very high in almost all the areas within Electrical Engineering, while they are significantly lower in almost all the other technology areas (see Figure 3).

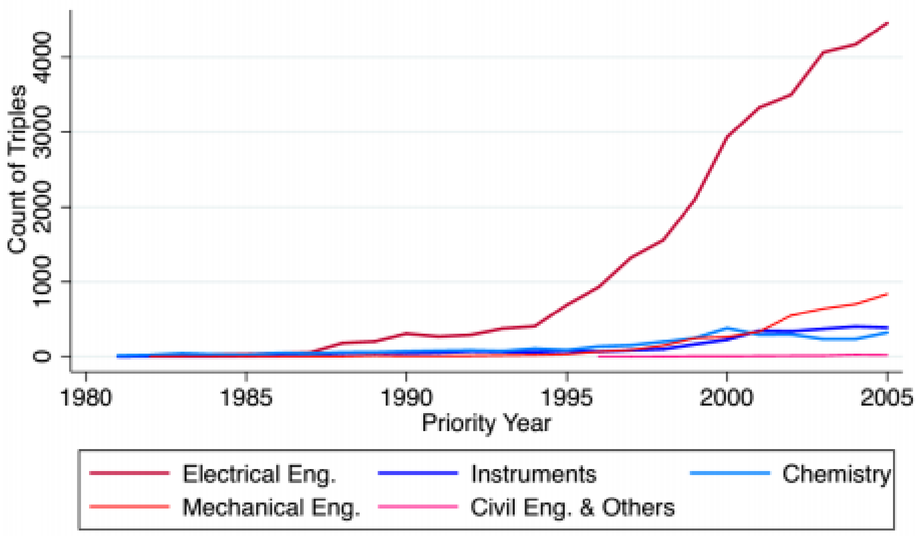

Figure 3: count of triples by main technological area and priority year (Source: Graevenitz et al., 2011)

Going a bit more into the details, Hall et al. (2013) find that, in Electrical Engineering, triple counts are particularly high in the areas of Telecommunications, Audiovisual Technology, and Computer Technology. Interestingly, they also find that a large share of the triple counts in Instruments accrue to patenting activity of some large ICT companies, such as Canon, Matsushita, Seiko, Epson, Sony, Ricoh and Samsung.

Effects of patent thickets

From a theoretical perspective, the consequences of patent thickets are not easy to predict and are likely to depend on firms and markets characteristics.

On the one hand, firms that rely heavily on the technology developed by competitors may have reduced incentives to invest in R&D as they fear to be held-up. At the same time, firms may need to build large patent portfolios to improve their bargaining position vis-a-vis rivals in the same technology area thus devoting a substantial part of their budget to patenting; also in this perspective, patent thickets are detrimental as they impact negatively on the resources available to firms for innovation. On the other hand, patent thickets may have positive effects on firms holding large patent portfolios due to the strategic advantage they confer. As this strategic advantage is likely to improve firms' profits, then patent thickets may provide additional incentives to R&D investments.

In principle the negative effects of thickets hurt mostly new entrants and SMEs, namely firms which are less able to pile up patents or companies that rely heavily on the technologies owned by competitors. On the contrary, large established firms holding sizeable patent portfolios may benefit from thickets, due to opposite reasons.

The empirical literature on thickets is relatively scarce mainly due to the lack of suitable data; nevertheless, the available contributions seem to confirm the above predictions and suggest that thickets may have differentiated effects depending on firm characteristics. Graevenitz et al. (2013) and Hall et al. (2013) proxy thickets with triple counts measured using information from the EPO. The former paper studies the effect of thickets on the patenting behaviour of 2,074 distinct firms filing applications between 1978 and 2003. Their analysis confirms that for complex technologies like telecommunications, large and small firms react to patent thickets differently; while firms holding large portfolios patent more intensively as thicket density increases, holders of fewer patents reduce their applications in response to larger and denser thickets.

Hall et al. (2013) focus their attention on how thickets impact on firms' entry defined as the decision to patent for the first time in a given technology area. They employ a sample of about 29 thousands UK SMEs observed over the period 2002-09. Using duration regression analysis they find that the propensity to patent for the first time in a given technology area is negatively affected by thicket density; again, this evidence confirms that small firms are those mostly harmed by thickets.

Other papers do not measure patent thickets directly but, rather, approximate their effects using the degree of prior art fragmentation. Ziedonis (2004) measures the level of fragmentation of prior art based on the number of competitors who are cited in the firm's patents; she shows that the more fragmented the prior art, the more aggressive the firm's patenting behaviour. This effect is stronger when the firm has sunk significant resources in technology-specific manufacturing equipment thus confirming that firms patent to insure themselves against the risk of hold-up.

On a similar vein of the previous studies, also Cockburn et al. (2010) find that fragmentation has differentiated effects on firms' performances depending on their characteristics; the authors examine the relationship between fragmentation and firms' innovative performance measured in terms of the share of sales from new products. They find a negative relationship between fragmentation and the innovative performance of firms needing to license the technology from rivals. In contrast, firms that do not in-license increase their share of sales from new products the greater the fragmentation.

In a recent workshop on patents thickets held at the EPO, experts in the field (practitioners, policy makers and academics) agreed that some root causes explaining the surge in patent thickets are likely to harm mostly SMEs and individual inventors. Small producers are unable to cope with what experts call the "costs of complexity", namely the costs associated with: the uncertainty over freedom to operate, the lack of transparency, the search of relevant prior art and legal actions (EPO, 2012b). At the end, workshop participants agreed that due to technological complexity patent thickets are a natural and, to a large extent, inevitable outcome in ICTs. Efforts must be put to limit their negative consequences by intervening on the slowness and cost of the patent system and by increasing the quality of patents.

In the rest of this section we focus on the institutional ways out to solve/ameliorate the inefficiencies due to patent thickets.

2.4 Patent thickets: way out

Historically, the two ways that market participants have used to address the problems associated with patent thickets are the creation of patent pools and the definition of standards through formal or informal standard setting organisations (SSOs). On top of these, recently, the patent aggregators have emerged in response to patent thickets, especially in ICT industries.

More generally, the negative consequences of patent thickets can be mitigated by a well-functioning market for ideas where to trade IPRs. We will discuss characteristics and the functioning of IP markets in the Section 2.5.

<u>Patent pools</u>

Patent pools can be defined as "an organisational approach in which two or more patent owners make their patents available as a bundle for a pre-defined (and openly publicised) price to any interested party" (Giuri et al., 2015).

Pools reduce transaction costs associated with a patent thicket as they represent a one-stop-shop through which a firm can access the package of patents belonging to several owners and reading on the relevant technology. Just to give a rough idea about the importance of patent pools, Clarkson (2003) estimates that in 2001 sales of devices embedding technologies based on patents licensed through pools were no smaller than $100 billion.

Patent pools require that firms collaborate closely; as such they are often under the scrutiny of antitrust authorities which fear that collaboration may favour collusion.

Three types of issues are relevant in order to evaluate the effects of patent pools. The first one, relates to the degree of substitutability or complementarity of patents forming the pool; the other two issues regard two clauses which are often included in patent pool agreements, namely the possibility of independent licensing and the grant-back requirement.

A well-established result is that pools are anti-competitive when they include patents that are perfect substitutes while they favour competition in the case of perfect complements (Shapiro, 2001 - Lerner and Tirole, 2004). When patents are perfect substitutes, the pool eliminates competition on royalties among holders of patents addressing exactly the same functionalities; therefore, in this case, the members of the pool benefit from reduced competition to the detriment of market efficiency as in a standard cartel. By contrast, when technologies are perfect complements, pools are pro-competitive as members internalise that larger royalties reduce the demand for complementary patents and, consequently, they are induced to lower licensing fees. In other words, with perfect complements, patent pools mitigate royalty stacking.

Lerner and Tirole (2008) highlight that these arguments apply neatly but only in the extreme cases of perfect substitutes/complements. In the reality, the distinction between complements and substitutes is not so clear-cut; for instance, technologies that today are complements may turn out to become substitutes in the future. On top of this, the same patents can be complements or substitutes depending on the level of their prices. Consider two technologies that are imperfect complements/substitutes; if their price is low, the two technologies are jointly employed and therefore they can be considered as complements. Conversely, if their price is high, users will consider them as substitutes thus employing just one of them.

In the intermediate cases of imperfect complements/substitutes, the consequences of patent pools are more nuanced. Lerner and Tirole (2004) extend the basic setting in order to describe this more general scenario; they show that the desirability of patent pools depends on a series of conditions such as the possibility of pool members to grant individual licenses, the ability of firms to invent around or their capacity to invalidate patents.

The second important issue to evaluate the effects of patent pools regards the possibility of members to license their patents also individually, independently of the pool. The effect of independent licensing is to increase competition on royalties and, as such, it tends to reduce prices and increase welfare. Lerner and Tirole (2004) show that independent licensing restores competition among pool members when the pool is aimed at raising royalties (as in the case of substitutes patents); on the opposite, when the pool is aimed at reducing royalties (i.e. complementary patents), independent licensing does not produce any effect.

Lerner and Tirole's arguments support the approach followed by competition authorities that often impose independent licensing to pool members; the authors, in fact, suggest that independent licensing reduces profitability of those pools aimed at increasing royalties, thus screening out bad pools. Lerner and Tirole (2008) conclude that, in the current state of knowledge, "the case in favor of pools with independent licensing is quite strong".

Grant-back clauses are the third issue potentially affecting the desirability of pools. With a grant-back clause, a member firm that obtains a patent which is considered essential to the working of the pool must turn such patent to the pool for free or at a low price. The desirability of grant-back provisions depends on a trade-off between incentives to innovate and the risk of hold-up. On the one hand, firms may be discouraged from innovating as they anticipate that grant-back clauses reduce their returns from licensing of future patents. On the other hand, grant-back clauses protect from members' opportunism; for example, as suggested by Lerner and Tirole (2008), a member may have an essential innovation ready to be patented but avoids disclosing it in an attempt to hold-up pool members. A grant-back provision prevents members from behaving in this opportunistic way.

While the theoretical literature on patent pools is quite well developed, empirical evidence on their efficiency is relatively scarce; a couple of papers has estimated the impact of patent pools on the innovative activity of both insider and outsider firms.[13] Joshi and Nerkar (2011) analyse data on innovation in the global optical disc industry and find that patent pools have substantially and significantly decreased both the quantity and the quality of patents subsequently obtained by insiders relative to the patenting activity of outsiders. Based on this evidence, the authors suggest that patent pools seem actually to inhibit, rather than stimulate, innovation by member firms. More recently, Vakili (2012) investigates the impact of the MPEG-2 pool focussing on the innovation rate of outsiders firms that are technologically proximate to the pool. Also in this case, evidence confirms the negative effect of the pool; the author finds that pool formation has substantially reduced outsider firms' innovation rate. However, by looking at the underlying mechanisms driving this result, Vakili (2012) finds that the observed reduction in innovation rates is mainly due to a shift in firms' strategy: investments in technological exploration seems to have been replaced by greater efforts in implementing the MPEG-2 technology in their own products.

Baron and Pohlmann (2015) argue that the decline in patenting by insiders and outsiders highlighted by the literature should not be interpreted as a causal effect of the pools themselves. According to the authors, in order to better understand the consequences of patent pools on innovation incentives one should also take into account the dynamics of patenting before the actual formation of the pool. More specifically, Baron and Pohlmann (2015) collect information on 50 patent pools in ICT industries; some of these pools were announced but then failed to take-off while others were also actually implemented. The authors find a significant increase in patenting just after the announcement of the pool; the effect is stronger for pools that were not only announced but that, later on, were also actually formed. Prospective members of the pool contribute the most to the increase in patenting in this pre-formation period. Based on these findings, authors conclude that "patent pools provide an instrument to monetize standard-essential

[13] Lampe and Moser (2010) and Mossoff (2009) investigate the effects of patent pools on innovation incentives by using historical data on the sewing machine industry of the late 19th century. The authors find that pools induced a reduction in patenting and innovation of member firms.

patents at a lower transaction costs, and hence make it more attractive for firms likely to join such a mechanism to file for additional patents".

Recently, an expert group made of industry participants, academics and experts of the field convened by the European Commission in 2013-14, set out a series of recommendations and best practices to foster the development of the patent markets with a focus on patent pools and funds (Giuri et al., 2015). According to these experts, the European Commission or the member states should consider supporting patent pools only in very specific circumstances such as when pools are aimed at promoting solutions to social challenges (e.g. the development of treatments for neglected diseases) or when they contribute to the advance of technological progress across member states. Interestingly, the expert group also recommends the possibility to include substitutable patents in pools when they are needed by standard implementers, provided that the additional royalties are small in relation to those for access to standard essential patents.

Standard setting organisations and FRAND licensing

The effects of patent thickets can be particularly severe when firms manufacture standardised products, namely interoperable products that adhere to a common technology, the standard. Standards are common in ICT industries; typically, high-tech products embed a large number of components that need to work well together in order to generate value; interoperability enables components to communicate seamlessly and invisibly to end users, thus giving rise to significant consumer benefits.

Firms may achieve interoperability through standard setting organizations (SSOs); SSOs serve as a forum where industry participants perform collaborative research and discuss the merits of alternative technologies. At the end of this process, SSOs endorse a particular technology and issue a formal certification (Simcoe, 2011); this certification signals the end of deliberations and promotes the adoption of the chosen standard by industry participants.

Well-known SSOs are the ETSI (European Telecommunications Standards Institute), the IEEE (Institute of Electrical and Electronics Engineers) and the ITU (International Telecommunications Union).[14] There are thousands of standards; ETSI alone has set more than six thousand standards including the various generations of mobile telecommunication technologies. Just to mention a practical example, a modern laptop computer incorporates nearly three hundred interoperability standards.

Standards often refer to patented technologies; a patent protecting a component deemed as essential to the standard is called standard-essential patent (SEP). In the presence of SEPs, manufacturers cannot produce standard compliant products without access to these patented technologies. As highlighted in Baron et al (2011), SSOs have good reasons to incorporate essential patents into the definition of the standard in order to reduce uncertainty and to provide incentives for firms to increase their efforts in standardisation. As a result, essential patents may actually accelerate the pace of standardisation.

The number of patents declared as essential has increased significantly in the last twenty years, also in the ICT industries (Meniere, 2015). The surge in SEPs also raises concerns about the potential hold-up they may generate. In principle, manufacturers of standard compliant products may mitigate the risk of being held-up by conducting a detailed patent search before starting their production. However, the large search and transaction costs in IP markets combined with the high degree of uncertainty over patents' scope and validity, often deters firms from conducting this investigation.

[14] ETSI, IEEE and ITU are examples of large established organisations which produce *de jure* standards; standards can also be set in less formalised consortia or *fora* which establish *de facto* standards.

Therefore, while SEPs are intended to reduce technological uncertainty and to accelerate standardisation, their proliferation may have the undesired effect to generate thickets and the associated hold-up problems.[15]

To address the thickets problem, many SSOs adopt IP policies that impose obligations on their members. Following Simcoe (2011), the two most widely adopted policies are:

a) disclosure rules: SSOs members are required to disclose relevant patents or pending patent applications;
b) FRAND licensing: SSOs members must license their standard essential patents on fair reasonable and non-discriminatory (FRAND) terms.

Disclosure rules have not proved to be very effective for at least two reasons (see Bekkers et al., 2011). The first one is that such rules often do not require firms to reveal specific pieces of their intellectual properties; as firms have little incentives in revealing their valuable IP, they are induced to make generic disclosures (the blanket disclosures) by indicating that they hold essential patents or applications without providing details on them.[16] The second reason for the ill-functioning of disclosure rules is that even when firms do provide specific information on their patents, they do so very late, when the cost of switching the technology for manufacturers implementing the standard has increased substantially. In this case, disclosure does not reduce hold-up.

FRAND licensing is also a very controversial IP policy. This rule obliges SEP owners to license their patents in a non-discriminatory manner; moreover licensing terms should fairly reward patent holders for their investments and for making their innovations available.

Until the 1990s, when SSOs started adopting FRAND policies, licensing negotiations took place among few and strategically similar companies, all involved both in the development and in the implementation of the standard. These vertically integrated companies typically ended-up cross-licensing their SEPs thus paying little royalties to each other. By contrast, today the increasing complexity of standards requires strong specialisation with the emergence of R&D-oriented companies on the one side and manufactures implementing the standard on the other. Clearly, these two types of companies have diverging interests and it has become increasingly more difficult to identify a consensual interpretation of FRAND licensing terms (Meniere, 2015).

Consequently, the ability of FRAND licensing to determine reasonable royalty rates on the one side and to prevent hold-up of follow-on innovations on the other are seriously undermined. The fragmentation of SEPs ownership around a standard may generate severe royalty stacking; just to take a relevant example, Armstrong et al. (2014) estimate that the potential patent royalty stack on a hypothetical $400 smartphone is at $120, approximately the costs of the components. FRAND commitments would not be suited to avoid hold-up either. As a matter of fact, negotiations occur after the standard has been actually implemented; this fact reduces the ability of FRAND licensing contracts to effectively prevent SEP owners from exploiting their bargaining position (Meniere, 2015).

Recently, the largest producers of mobile computing, telecommunications devices and software – Samsung, Microsoft, Apple and Motorola among others – engaged in a high-stakes battle over the infringement of dozens of patents, including several SEPs subject to FRAND commitments.[17] This

[15] In a recent theoretical paper, Lerner and Tirole (2013) present a tractable framework to analyse the most important trade-offs arising in the determination of the licensing terms of standard essential patents. The authors argue that inefficiencies are related to the lack of price commitments. In their study, the authors also show that price commitments are unlikely to emerge in the absence of regulation.

[16] Simcoe (2005) shows that half of all disclosures fail to identify a specific patent or patent application, and ninety percent do not provide information about pricing.

[17] The role of SEPs in igniting the smartphone war has been questioned by Gupta and Snyder (2014). According to the two Qualcomm researchers, litigations have been primarily driven by patents that are not

"smart-phone war" is often considered as an example of the problems associated with FRAND licensing; it involved value of products measured in billions of dollars and huge royalties.[18]

It is commonly accepted that the process of FRAND bargaining needs to be better framed and that much needs to be done in order to reach consensus on the determination of fair and reasonable royalties. One of the critical issues regards the lack of transparency which generates transaction costs. Meniere (2015) lists some possible interventions aimed at increasing transparency, including the public disclosure of licensing terms by SEPs holders. Other relevant issues regard the quality of SEPs and the governance of SSOs. As discussed above, the low quality of patents is a concern for the whole system of IPRs, even the more so for patents around ICT standards. Tighter collaboration between SSOs and PTOs can mitigate this problem. Good examples of collaborations are the partnerships established between the EPO and the European Telecommunications Standards Institute (ETSI) and the Institute of Electrical and Electronic Engineers (IEEE).

2.5 The market for ideas

One of the roles of patents is to favour the market for ideas, thus addressing Arrow's appropriability problem. As a matter of fact, a market for ideas that functions well could also mitigate the distortions caused by the presence of low-quality patents as well as by the proliferation of thickets. Empirical evidence suggests that the market for ideas has grown during the last decades (see Arora and Gambardella, 2010 for a recent survey). For instance, in a study on the international trends in royalty and licensing revenues, Athreye and Cantwell (2007) estimate in $90-100 billion the worldwide market for technology for the year 2000, with a growth rate of about 5.6% during the period 1990-2003, a notable figure which is twice as big as the growth rate of world GDP in the same period.[19] Similarly, based on a sample of 600 European firms, Zuniga and Guellec (2008) find that about a fifth of European companies licenses patents to non-affiliated firms.[20] The two authors also observe that, between 2003 and 2006, licensing has increased in importance for about 45% of the firms in the sample. Interestingly, Zuniga and Guellec (2008) report that SMEs have more difficulties to license out their patents than large firms; the difficulty in identifying potential partners is the main obstacle to licensing for smaller companies. Looking at the sectorial level, ICT firms appear to be largely involved in technology licensing. Sheehan et al. (2004) find that, during the 1990s, (inward) licensing had increased for 60% of the surveyed ICT companies and that for 39% of them licensing is a "very important" motive for patenting (compared to about 19-29% for companies belonging to other sectors).[21]

However, despite these growing numbers, the market for ideas appears to be prone to failures. For instance, in a study based on the PatVal survey, Gambardella et al. (2007) observe that asymmetries of information and search costs severely limit technology licensing. According to the authors, should these frictions be removed, the number of licensed patents would increase considerably, from 11% (percentage of patents that are actually licensed) to around 18%. On the

related to the standards. They argue that the smartphone war is mainly due to the aggressive behaviour of new and large industry entrants.

18 In light of the recent disputes involving SEPs, standard setting organisations are reconsidering their IP policies. Just to take a relevant example, in March 2015 IEEE substantially reviewed its policy with the aim of limiting/avoiding the use of standards-essential patents to block competitors; for a discussion of the new IEEE IP policy see Lindsay and Karachalios (2015).

19 Arora and Gambardella (2010) argue that Athreye and Cantwell (2007) might overestimate the size of the market for ideas. Their figures also include transactions among affiliated entities (rather than market transactions) as well as payments for packaged software, trademarks and copyright.

20 Zuniga and Guellec (2008) analyse also Japanese firms. Using a sample of 1,600 companies, they show that more than 25% of the Japanese sample licenses patents to non-affiliated firms.

21 The authors base their analysis on data collected in a survey on 105 European and North American large companies.

basis of these estimates, it follows that the European market for patents could be, approximately, 70% larger than what actually is.[22]

Drawing from the literature on market design (Roth, 2007 and 2008), Gans and Stern (2010) identify the most important failures characterising the patent market. The two authors argue that inefficiencies arise for a number of reasons.

1. Patents are inherently difficult to evaluate. Each negotiation is to a large extent "unique" so that little information about patent value can be drawn from other market transactions.
2. There are important portfolio/complementarity effects. With complex technologies, such as those characterising ICTs, innovations are covered by a number of different patents. In such cases, the acquisition of a single patent is of little value, unless other complement patents are acquired as well. Portfolio effects reduce the number of potential buyers, thus making the market less liquid.
3. Search costs are high. Both for would-be licensees and would-be licensors the cost of identifying potential buyers or sellers of the technology are substantial. This is all the more so as the number of patents reading on the relevant technologies/products gets larger.
4. Negotiations take place in the shadow of litigation and licensing terms heavily depend on the opportunity cost of going to trial for the involved parties rather than on the actual value of the patent.

Another important source of transaction costs often brought up by industry experts and analysts regards the fact that when intellectual property changes hands, there is often no record of the transaction. This generates a lack of transparency which can create uncertainty over who is in the market, what their intentions are, and whether their property is already licensed. This lack of transparency leads potentially to more infringements, higher transaction costs, and higher costs for dispute resolution (EPO, 2012). On these issues, Giuri et al. (2015), investigating possible interventions to foster the development of patent markets, insist that the EPO and the European Commission should explore the feasibility of requiring the registration of patent ownership and changes in ownership. In addition, patentees should be encouraged to declare their willingness to license out their patents. These recommendations would help enhancing patent market efficiency. On top of these interventions, the group of experts has also argued that EPO should make all the efforts to maintain the high quality of European patents also in the future, possibly even increase it provided that this does not lead to a lengthening of the patent procedures.

According to Hagiu et al. (2011) patent market inefficiencies are particularly harmful for individual inventors and SMEs. By combining information taken from several different public sources, the authors find that, indeed, in the United States, large companies contribute about to 40% of all patents but obtain 99% of the revenues generated through licensing. Therefore, market distortions reduce the ability of small firms and inventors to monetise the value of their patents.

Patent intermediaries

In principle, patent market intermediaries may play a crucial role in curbing the inefficiencies characterising IPRs negotiations. In a recent study Hagiu and Yoffie discuss the merits of several different types of intermediaries (see Hagiu and Yoffie, 2013). According to the authors, "traditional intermediaries" such as brokers, patent pools and standard setting organisations play a limited role in mitigating market distortions. Patent brokers facilitate the sale or the licensing of patents but tend to focus on high-end transactions only. Patent pools and standard setting organizations,

[22] The presence of frictions limiting the efficiency of the market for ideas is confirmed also in the second wave of the PatVal survey (Torrisi et al., 2014). The authors observe that a significant share of patents are "sleeping", namely patents they are not used and that owners are unable to transfer to third parties in the market for technology.

instead, emerge under very specific conditions characterising the industry. Evidence suggests that patent pools arise especially when multiple marginalisations/royalty stacking represents a severe problem, substantially limiting the scope for technology licensing. Standard setting organisations, instead, typically emerge in industries where interoperability of several different technology components is crucial; hence, the scope of SSOs appears to be limited to a small number of sectors.

A series of new patent intermediaries have emerged during the last years. According to Hagiu and Yoffie (2013), some of them, for instance patent auctions and "ebay-like" online patent marketplaces, address some of the distortions characterising patent markets[23] but are unlikely to represent a real fix to inefficiencies. Evidence suggests that these intermediaries have typically failed to gain the attention of both sides of the market (licensors and licensees). In addition, even though auctions and online marketplaces may reduce search costs they seem to be inherently unable to address the classical Arrow's appropriability problem. As a matter of fact, potential sellers are reluctant to reveal detailed information on their technology online; patent-related transactions often need a "close-touch" between buyers and sellers and this undermines the efficacy of online marketplaces.

According to Hagiu and Yoffie (2013), a more promising type of intermediaries are the patent aggregators. The two authors distinguish between defensive aggregators and super-aggregators. Defensive aggregators offer their clients a sort of "insurance" against patent trolls. More specifically, defensive aggregators identify and purchase patents that might threaten their clients (who, in turn, pay annual subscription fees to the aggregator or contribute directly to the purchase). These patents are then licensed by the aggregator to its clients for use in countersuits against patent trolls. Super-aggregators act both defensively, by licensing the acquired patents to their clients/investors, and also aggressively by suing third parties in search for licensing revenues. In this latter respect, super-aggregators are considered as a form of patent assertion entity which we will discuss below. Probably, the most well-known super-aggregator is Intellectual Ventures which, by holding approximately 35,000 patents concentrated in ICTs sectors, represents the third-largest patent portfolio world-wide. Intellectual Ventures' investors include prominent technology companies such as Amazon, Apple, eBay, Google, Intel, Microsoft, Sony, Samsung, etc.

Although aggregators originated in the US, they are effectively operating also in Europe where they are expected to expand their activities. Aggregators are a relatively recent phenomenon which deserves to be better understood and investigated. Experts argue that despite their presence there are no accurate statistics describing the extent of their activities in Europe (EPO, 2015b).

Patent assertion entities (PAEs)

One of the most controversial phenomena related to the market for ideas is the emergence of the patent assertion entities (PAEs). PAEs, often referred to as non-practising entities or patent trolls, acquire patents not for production or follow-on innovation but only to collect revenues from licensees or from alleged infringers. During the last years, patent litigation involving PAEs has increased drastically. For instance, Chien (2013) estimates that, in the year 2012, nearly two-thirds of patent lawsuits in the US were initiated by a PAE (about 2,900 out of 4,700 of the cases), with a marked increase with respect to the previous years. According to RPX Corporation, a company providing its clients with different forms of protection against patent trolls, legal and settlement costs related to PAE litigation skyrocketed to $12.2 billion in 2014.

Born as a US phenomenon, PAEs have already crossed the Atlantic, though their incidence is lower in Europe than in the United States (de Bisthoven, 2013). To the best of our knowledge, Helmers et al. (2013) is the only paper analysing the role of PAEs within Europe. The authors look at patent

[23] Patent auctions are an effective way of eliciting the value of patents while online marketplaces help in reducing search costs.

litigation cases involving PAEs in UK and they find that patent assertion entities were responsible for about 11% of the patent suits filed in the United Kingdom between 2000 and 2010 (33 cases out of 300). According to the authors, one of the important factors explaining the lower frequency of litigation cases initiated by PAEs in UK compared to the US is related to the "loser pays" rule for the allotment of legal expenses; as a matter of fact, the risk of being liable of large legal fees deters PAEs from filing legal suits. Helmers et al. (2013) argue that the different rule for the allotment of attorney fees is more relevant in explaining the lower impact of PAEs than the traditional arguments which commonly refer to the higher barriers to patenting software, the lower cost of defense or the smaller damages awards that characterise Europe and UK when compared to US. Looking more closely to the parties involved in the trials, Helmers et al. (2013) find that PAEs overwhelmingly assert high-tech patents: three out of four of the companies accused of infringing a PAE patent belong to ICT industries; moreover, about 71% of the suits involve at least one software patent.[24]

PAEs are a relatively recent phenomenon and, besides increasing litigation, it is still unclear how they impact on the patent market. For instance, Haus and Juranek (2014) argue that PAEs make the market more liquid, thus increasing its efficiency. The authors base their arguments on an empirical investigation with information on 779 US patent litigation cases. They find that patent assertion entities are more likely to sue large and technology intensive firms and interpret these results as evidence that PAEs help small and financially constrained innovators to exploit the full value of their patents; by selling their IPRs to PAEs these innovators are able to cope with large competitors and to increase the payoff from their intellectual property.[25] Hagiu and Yoffie (2013) appear to be less positive about PAEs. They observe that some practices employed by patent assertions entities are unlikely to increase market efficiency. As a matter of fact, PAEs tend to sue target-companies at times when they are most vulnerable, "like just before the release of a new product, when the target can ill afford a risky trial". Furthermore, by not being active in production, PAEs have the advantage that they do not risk to be counter-suited (de Bisthoven, 2013). Pohlmann and Opitz (2013) hold a more nuanced view on patent assertion entities. Based on a series of case studies, they argue that PAEs may help small firms enforcing their IPRs; however, the authors suggest that patent assertion entities also lead to excessive royalty fees and increase negotiation costs. Pohlmann and Opitz (2013) conclude that PAEs "might have negative effects but may also cure failures of the patent system."

Finally, an emerging issue concerns the role of the Unitary Patent system in favouring or discouraging PAEs. De Bisthoven (2013) observes that the alleged advantages of the new system (for instance the reduction in patenting costs) certainly favour PAEs' activities. However, the author argues that even though the reform appears to be a bit too "pro patentee" in some aspects, patent assertions entities should not be considered as the main concern of the patent system. Policy makers should care more about the overload of patent offices which often results in granting low-quality patents. According to Helmers et al. (2013), the new EU unitary patent package includes some provisions safeguarding from patent misuses by PAEs; in particular, the presence of the "loser pays" rule according to which attorney's fees are awarded to winning litigants should discourage trolls abuses. A similar view is held by de Bisthoven (2013) even if he also recognises that some remedies to the abusive behaviour of PAEs should be pursued more actively by policy makers. For instance mandating "industrial exploitation" would oblige patent trolls to become "practising entities" or to grant compulsory licensing. Similarly, taxing trolling businesses at different levels could help in scaling down PAEs' activities.

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24 For the US, Chien (2013) observes that PAEs are increasingly suing companies in low-tech industries even though, historically, patent trolls were a "tech" problem.

25 The same view is shared by Chien (2013) who observes that "My research has documented the positive impacts of a liquid IP market, and that startups are selling to trolls and benefiting from that monetization."

3. Copyright

Copyright protects a wide range of artistic and scientific works, from literary to music works, from maps and technical drawings to photographs, from cinematographic works to paintings and sculptures. As regards, specifically, high-tech products, software programs and databases are protected by copyright. On top of that, also multimedia products combining several types of works in a fixed medium such as a computer disk or a CD-rom are eligible for copyright protection. Examples of multimedia products are videogames, information kiosks or interactive webpages involving the combination of many different creative works, such as graphics, text, music, photographs, databases, videos, computer software, etc. (WIPO, 2006). Copyright protects each of these elements separately as well as the particular way they are arranged to form the multimedia product, provided that the combination results in an output which is deemed to be original.

As shown in Table 1, in Europe all ICT service industries, with the exception of wireless and satellite telecommunications activities, are copyright intensive. Unlike for patents and trademarks, copyright is not registered; the definition of copyright intensive sectors used in EPO and OHIM (2013) is based on the methodology developed by WIPO (2003) which classifies industries according to the degree to which firms activities rely on copyright.

Copyright grants the creator of an original work the exclusive rights to control, use and distribute the work for a limited period of time.[26] Protection is granted automatically without prior test of the quality of the original work and it does not require any formal registration; it applies not to the idea but rather to its expression in whatever mode or form. Copyright is granted by national laws and the geographical scope of protection is limited to the territory of the relevant member state. Nonetheless, national legislations depend increasingly on statutory provisions of the EU. In 2001 the European Parliament approved a Directive on the harmonisation of certain aspects of copyright and related rights in the information society (2001/29/EC); the Directive was aimed at adapting legislations on copyright and related rights to technological developments and to implement two WIPO Internet treaties (the WIPO copyright treaty and the WIPO performances and phonographs treaty). The scope of the Directive was to harmonise different rights crucial for the digital transmission of works and it was extremely controversial since its approval, with only Greece and Denmark that implemented it within the statutory deadline. Italy, Austria, Germany and the UK implemented it with some delay, while other countries were convicted for non-implementation.

3.1 Economics of copyright

The economic rationale for copyright protection parallels in many respects that of patents (see Landes and Posner, 1989). Artistic works are public goods as they can usually be reproduced at low cost and enjoyed in a non-rival way by consumers. Copyright protection excludes individuals from consumption, thus granting creators a monopoly position and generating economic incentives to conceive and produce the artistic work.

More specifically, as discussed in Liebowitz and Watt (2006), optimal copyright protection should balance two opposite goals: stimulate production of artistic works on the one side and guarantee consumption of such works on the other. According to the traditional view, these two goals are to a large extent irreconcilable: given the public good nature of an artistic creation, absent any protection of the intellectual property, competition would efficiently drive the price of the creation down to the marginal cost of production, thus maximising consumption and consumer welfare. Nonetheless, at this price creators would not be compensated for their creative efforts and this will ultimately lead to underproduction of artistic works. The solution to this dilemma is to give creators

[26] Internationally, the minimum term of protection is 50 years, plus the life of the author but in many countries this limit has been raised up to 70 years plus the life of the author.

the possibility to exploit part of consumer willingness to pay for the work by granting them the right to legally exclude free-riders via copyright.

The very need to protect artistic creations has been questioned by economists since the early studies on copyright. These studies, written well before the advent of digital technologies, argue that the benefits of lead time as well as the presence of non-monetary incentives are sufficient to stimulate artistic creations (Plant, 1934 and Hurt and Shuchman, 1966). More recently, Boldrin and Levine (2008) suggest that, on top of lead time, creators of artistic works benefit from a competitive rent. Boldrin and Levine (2008) argue that the traditional view according to which for unprotected works the price would immediately converge towards the marginal cost is wrong, as it mixes-up short-run with long-run perspectives. In the short-run, the overall capacity (of both the creator and imitators) is limited so that the equilibrium price is above the cost of production, thus allowing the creator to obtain a monetary benefit. More specifically, copyright, as well as the other mechanisms of IP protection, grants inventors two rights: the first one is the "right to sell the first copy", that is the inventors' right to sell their innovation. The second one, which Boldrin and Levine critically define as "intellectual monopoly", refers to the inventor's right to regulate the use which can be made of the innovation. According to the two authors, the right to sell the first copy is enough to stimulate the creation of artistic works; therefore IP laws would provide inventors and creators with an excessively strong protection with the consequence of hampering innovation and technological progress, rather than promoting it. Boldrin and Levine's provocative view has certainly the merit of highlighting one of the most debated issues regarding copyright, namely the fact that it would confer excessive protection to the copyright holder; nonetheless, the arguments put forward by the authors seem less appropriate to describe the efficacy of copyright protection in the digital world. As we will discuss below, with file sharing technologies, copyrighted works can be easily and almost instantaneously reproduced without capacity constraints. In this environment, imitation is likely to substantially limit the right to sell the first copy, thus impacting on the revenues artists are able to collect.

Other authors have pointed out that it is also possible for copyright holders to benefit from reproduction of their artistic works (see Belleflamme and Peitz, 2010). The possibility of duplicating a product, for example a book which can be photocopied, represents certainly a positive and valuable aspect for consumers. The key point here is that duplicability may also be positive for the copyright holder when she can, partially or entirely, appropriate this greater value. This is the idea of the "indirect appropriability", introduced by Liebowitz (1985) in a study on scientific journals. The author argues that the ability to make copies may increase consumer willingness to pay for originals and, thereby, allows producers of originals to capture the value of these copies. Indirect appropriability may be possible when the publisher is able to discriminate between users who are interested in duplicating the original and those who are not, thus charging a higher price to the former set of users.

Landes and Posner (1989) argue that copyright protection increases the cost to develop derivative works; follow-on creators may have reduced incentives to build upon existing works as they have to obtain the permission of copyright holders. These arguments are reminiscent of the hold-up problem discussed in the patent literature and, as in the case of patented technologies, efficiency can be restored by means of an effective market for copyright licensing. Digital technologies make it extremely easy to combine existing content to develop new artistic works and services. In this context, it is particularly urgent to create an efficient market for copyright licensing. Hargreaves (2011) presents several examples of inefficiency in copyright licensing in the UK. For instance, the author reveals that it took nearly five years to the BBC to assemble the rights needed to launch its iPlayer service. Hargreaves (2011) also discusses a series of cases of small providers of content services reporting difficulties in collecting rights to use copyrighted works; these cases reveal that inefficiencies in copyright licensing are very much likely to harm small companies. The most debated proposal in the Hargreaves' report is the creation of a hub for the exchange of digital rights, the Digital Copyright Exchange. This hub should provide a market place facilitating the licensing of copyrighted works through automated web-based computer systems. Following Hargraves' proposal, in March 2013 the UK Government announced a funding of £150,000 aimed at the creation of a UK-based Copyright hub; in July 2013, the Copyright hub's pilot website went online. It is worthwhile stressing that the development of a pan-European licensing for copyrighted works is also one of the pillars for the establishment of the Digital Single Market in the European Union.

One of the emerging issues related to copyright and digitisation regards the need to guarantee cross-border accessibility of digital media content. As matter of fact, when travelling across the EU, consumers are often prevented from using the content services for which they have paid for in their home country. Similarly, on the supply side, a service provider cannot operate in countries for which it has not acquired a licence for making the content available online. These frictions may substantially contribute to an increase in transaction costs and limit the scope of the Digital Single Market. By using data from the Apple iTunes European country stores, Gomez and Martens (2015) show that the geographic segmentation of digital EU markets is still significant. For instance, the authors find that availability of media products across country stores in the EU is around 80% for music and 40% for films, still far from the 100% mark.[27]

3.2. Empirical literature: copyright and digitisation

The optimal scope of copyright protection is an inherently empirical issue. The very nature of copyright is to protect artistic works; not surprisingly, rather than in ICTs, the vast part of the literature has focussed on the impact of copyright in creative industries such as music, film, publishing etc.. In what follows, we briefly review some of the most influential works in this literature;[28] the Section on software complements the evidence we provide here.

One of the mostly debated issues in the empirical literature concerns the ability of authors to earn money out of copyright royalties or from other sources. Connolly and Krueger (2006) study the earnings of artists in the rock and roll industry and find that concerts rather than royalties represent the most important source of income for performers. However, the authors stress the fact that even though royalties do not represent the main source of earnings for musicians, it does not necessarily imply that copyright is worthless. As a matter of fact, earnings obtained in activities other than recording royalties may be still attributable to the presence of an exclusive right. This amounts to say that the ability of collecting revenues from concerts and touring does, to a certain extent, depend also on the presence of copyright protection. Kretschmer and Hardwick (2007), in an extensive empirical investigation on writers in Germany and UK, and Hansen et al. (2003), in a study on composers, lyric writers and arrangers of music in Finland, cast even more serious doubts about the efficacy of copyright. These papers show that the vast majority of artists do not manage to collect significant revenues through royalties and they often have a second source of remuneration of some kind. From these contributions it does not emerge a strong case in favour of copyright as an incentive mechanism for artistic creations.

The more recent literature on copyright has mainly focused on the impact of digitisation.[29] The digital revolution with the rapid diffusion of powerful new copying technologies such as file-sharing networks as well as CD- and DVD burners, has made it extremely easy to copy, duplicate, and exchange information goods such as software, music, films and books. These technologies significantly diminished the extent of protection provided by copyright and have greatly impacted on the behaviour of both consumers and content producers.

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[27] On the same lines, Martens (2013) argues that across member states trade costs associated with copyright clearance have not disappeared.

[28] See Watt (2009) for a detailed survey of the empirical literature on copyright.

[29] See Handke (2010) for an extensive survey.

Empirical studies on the effects of piracy and file sharing have taken different angles. One of the most debated issues investigated by the empirical literature, regards the impact of file sharing on sales of authorised copies. The conclusions emerging from this literature are not so clear-cut. Peitz and Waelbroeck (2004) use data on CD sales and on mp3 downloads and find a significant negative correlation between them. However, when looking at the substitution effect of mp3 downloads for CD purchases they find that downloads explain only a fraction of the decrease in sales.

Michel (2006) uses micro-level data from the Consumer Expenditure Survey, from 1995 to 2003, to examine the impact of file sharing on music sales. He finds that file sharing may explain a reduction in sales of up to 13% for some consumers.

The debate on the effects of file sharing on authorised sales has also been fuelled by the work of Oberholzer-Gee and Strumpf (2007). The two authors use weekly data on downloads and album sales and conclude that file-sharing has an impact on sales which is "indistinguishable from zero". This work has stimulated a hotly debate on the effects of file sharing and has been strongly criticized by Liebowitz (2007).

An interesting analysis is conducted in Rob and Waldfogel (2006). The authors investigate the impact of file sharing on the purchasing behaviour of a sample of US college students and find that the rate of substitution between illegal downloads and authorised purchases is about 0.2. Interestingly, Gopal et al. (2006) show that file sharing entails important sampling effects. By conducting a survey on 200 college students in the US, they find a positive relationship between on-line sampling and the reported propensity to purchase authorised copies. Gopal et al. (2006) reveals that file sharing technologies have differentiated effects depending on artist characteristics, as they seem to erode superstars market shares. As a matter of fact, consumers tend to choose the most popular artists in order to minimise sampling/search costs; as file sharing reduces, if not eliminates, such costs, it benefits emerging artists. This result is to a large extent confirmed by Tanaka (2007) who, by using micro data on music CD sales in Japan, finds that peer to peer file sharing systems stimulate the sales of high quality music, while reducing those of low quality music. These findings suggest that file sharing websites make consumers search activities more effective.

Digital technologies undoubtedly facilitate piracy and hamper copyright protection. Following the traditional view, one would expect this reduction in protection to be accompanied by lower incentives to create artistic works; at a macro level, illegal access to copyrighted works would translate into less economic growth.

As regard the impact of digital technologies on the incentives to create, little evidence is available. Waldfogel (2011) studies the effects of Napster on the release of new albums. By comparing the availability of albums before and after the advent of Napster, he finds that the peer to peer system did not affect the quantity of new recorded music or artists coming to market. The increase in new works since the advent of Napster is confirmed also in Aguiar et al. (2015); using North American and European consumption data, the authors show that also the quality of new works has increased. They explain this growth in quantity and quality arguing that digitisation has caused a reduction in costs that more than compensate the drop in revenues.[30]

A more worrying picture emerges from the studies on the impact of digital piracy on economic growth. Frontier Economics (2011) draws on the most recent industry and academic studies to provide a consistent estimate of the value of digital piracy across the movie, music and software

[30] An interesting report by JRC discusses the changing roles of copyright in the digital era (Simon, 2012). The author urges for a change of the system in order to accomplish with the new challenges posed by the advent of digital technologies.

industries.[31] The report finds that the total value of digital piracy for 2008 in OECD countries has been close to $75 billion. As not all illegally downloaded digital products are substitutes for legal sales, this figure overestimates the loss in revenues; nonetheless, there are no doubts that digital piracy significantly erodes firms' revenues, with a potentially negative impact on employment in creative industries. In 2010, TERA Consultants prepared a report on the economic impact of Internet piracy in the EU (see TERA, 2000). The study focuses on Germany, France, the UK, Italy and Spain and estimates that in 2008 the EU had lost 186,600 jobs as a consequence of Internet piracy.

Overall the effects of digital piracy are still very much debated. On the one side, there is evidence that piracy reduces sales and profitability with potentially negative effects on investments, employment and growth in creative industries. On the other side, available evidence does not always support the view according to which piracy is the sole responsible for the decrease in sales and it shows that often artists collect important shares of their income from sources other than copyright exploitation.

4. Trademarks

Trademarks protect distinctive signs such as words, images, pictures, logos, shapes, sounds or combinations of these elements that allow firms to make their products or services distinguishable from those of competitors. Trademarks must fulfil several requirements the most important of which is distinctiveness: consumers must be able to recognise the sign as trademark, clearly distinguishable from other trademarks in the same field. Protection is generally granted on the basis of a registration through the Patent and Trademark Office;[32] applicants can obtain protection at the national level or, by filing the application at OHIM, at the European level (community trademarks). Registration grants the owner the exclusive right to use the trademark on the goods or services in the product classes in which it is registered; the owner can prevent competitors from using the same sign or a similar one. In addition, trademarks can be sold or licensed to third parties.

Trademarks are probably the IP instrument which is most commonly employed by companies. Graevenitz et al. (2012) survey trademark applications in the US during the last century and show that there has been a marked surge in branding activities during the last three decades. A similar finding is in Jensen and Webster (2004) who compare the experiences of US, UK and Australia. The two authors argue that the rapid increase in trademarking registered during the last decades is mainly a demand-driven effect; rising consumer incomes have increased the demand for more product differentiation and higher product quality. Cost-driven effects (the growth in production which led to more firms and products) also contributed to the surge in trademarks even though to a lesser extent. As already shown in Table 1, with the exception of "Manufacture of loaded electronic boards" and "Repair of computers and communication equipment", ICT industries are trademark-intensive. This fact is also confirmed in OECD (2014) where it is shown that trademark registrations of ICT-related products in the period 2010-13 have reached about one third of total trademark filings at the European Office for Harmonisation in the Internal Market, and one fifth at the United States Patent and Trademark Office.[33] This evidence partially contradicts previous

[31] The report identifies the volume of digital piracy and computes its value of it by using the average price of legitimately available digital products.

[32] In some countries registration is not compulsory and protection is granted upon use of the distinctive sign (unregistered trademark).

[33] There are concerns about the measurement of ICT trademarks; trademarks are in fact classified according to the Nice Agreement which does not explicitly denote ICT products and services as distinct classes. This lack of classes requires a text based counting which may give imprecise measures of ICT-related trademarks (OECD, 2014).

findings in the literature according to which trademarking is concentrated in scientific equipment and pharmaceutical sectors as well as in clothing, footwear, detergents and food products (Baroncelli et al., 2005), in service industries, including communication, education, and personal services (Jensen and Webster, 2004), and in the retail sector as well as in hotels and catering (Greenhalgh and Rogers, 2008).

The economic rationale for trademarks is well understood since Landes and Posner (1987). Trademarks make it possible for companies to set their products apart from those of rivals, thus reducing consumer search, and allowing firms to differentiate their products, or to implement more modern forms of commerce such as franchising or brand extension. The very nature of trademarks is to mitigate/eliminate information asymmetries among sellers and buyers, a market failure which is different from that addressed by patents and copyright. Nonetheless, as also observed by Landes and Posner (1987), by potentially increasing the returns firms are able to collect, trademarks also raise the incentives to invest in quality and reputation.

4.1 Trademarks and innovation

The empirical literature on the effects of trademarks on firms' performance is relatively scarce. According to Hall et al. (2014), most of the studies focus on the relationship between trademark ownership and firm value; from this literature it emerges that trademarks are more important for service sector firms. The relationship between trademarks and innovation is investigated in a series of studies recently surveyed by Schautschick and Greenhalgh (2013). Overall these investigations find a positive correlation between innovation and trademarking activities. This is what is shown in Allegrezza and Guard–Rauchs (1999); by looking at a relatively small sample of industries, the authors find a positive association between trademarks and R&D intensity at the firm level. Jensen and Webster (2009) employ survey information about the innovative activities and the IP strategies of more than 1,000 Australian companies. For the manufacturing sectors, the authors find a positive and strong correlation between innovation activities and trademarks. Also in services, innovation and trademarking are positively correlated, even though the relationship is weaker. Differences emerge also when looking at the type of innovation. Product and marketing innovations are correlated with trademarks; the correlation between process innovation and trademarking is still positive but weaker. By contrast, Jensen and Webster (2009) find a negative correlation between organisational innovations and trademarks.

These results are largely confirmed by a more recent investigation on about 20,000 French firms (Millot, 2012). As a matter of fact, the author finds a positive correlation between trademarking and innovation in both product and marketing activities. Process and organisational innovations are instead uncorrelated with trademarking activities. The study by Flikkema et al. (2010) confirms the positive association between innovation and trademarking and highlights that trademarks may represent a useful measure of innovation, complementing other commonly used proxies such as patents and R&D expenditures. More specifically, the authors employ survey information on 660 companies with trademarks registered in Benelux. They find that nearly two thirds of the trademarks refer directly to a broad range of innovative activities; interestingly, trademarks are filed close to the launch of the new products or services. Therefore, trademarks may represent a useful measure for the innovations occurring in the late stages of development; typically, patents and R&D expenditures are ill-suited to measure this kind of innovation.

4.2 Trademark cluttering

The impressive surge in registered trademarks raises concerns that somehow parallel those related to patent thickets. The expression "trademark cluttering" describes a situation where trademark registers contain such an increasingly large number of unused or overly broad trademarks that the cost of creating new ones substantially increases for later applicants; these companies may have greater difficulty in making their products clearly distinguishable from those of competitors. A recent report of the UK Intellectual Property Office is devoted to looking more closely to trademark cluttering (Graevenitz et al., 2012). The authors highlight three mechanisms that contribute to cluttering: i) firms apply for more classes than are actually needed for the current use; ii) in regulated industries (such as pharmaceuticals) firms apply for more trademarks at the same time, provided that regulators might reject some of the proposed names; iii) firms may anticipate a broadening of their product range and register extensions of their existing trademarks.

Looking at the consequences of cluttering, Graevenitz et al. (2012) report the results of a survey conducted by the Institut fuer Demoskopie Allensbach and the Max Planck Institute for Intellectual Property, Competition and Tax Law on a random sample of 1,599 "trademark users", that is trademark owners or trademark attorneys. The authors find that about 21% of trademark owners consider cluttering to be a problem; a larger percentage (29%), instead, does not consider it as an issue. These percentages change slightly in the group of trademark attorneys. About 41% of the surveyed attorneys consider cluttering to be a problem whereas only 33% do not. Graevenitz et al. (2012) conclude arguing that there is no strong evidence that cluttering has already become a systemic problem; nonetheless, it is worth looking more closely to this issue.

5. IP bundles

The prevailing approach when analysing firms' IP strategies has been to focus on the different types of IPRs separately; the underlying assumption of the literature is that the various IP instruments are, at least to a certain degree, substitutes. However, the preliminary evidence shown in the introduction seems to suggest that ICT firms tend to protect their innovations by using combinations of two or more IPRs (IP bundle in the economics jargon). As a matter of fact, according to the EPO and OHIM (2013) estimates, in several ICT industrial sectors firms make an intensive use of more than one IPR.

This is certainly not surprising; firms may naturally use combinations of IPRs as the different rights address specific needs. For instance, a patent protects the inventor from imitators while a trademark promotes efficiency by reducing consumer search costs. On top of this, high-tech products and technologies typically combine different components eligible of separate IP protection. For example, as reported by Graham and Somaya (2006), the software company HiddenMind Technology Inc. registered the trademark ActiveUniverse® and, at the same time, it used patents to protect the associated product idea and copyright to protect the software source-code.

The economic literature on IP bundles is scarce. The few theoretical contributions focus on determining whether IP rights are substitutes or complements. Graham and Somaya (2006) argue that IPRs are essentially complements; they highlight two possible sources of complementarities: market and cost driven. Market-driven complementarities arise when a more aggressive use of one IP instrument stimulates demand, thus increasing the benefits of using more intensively also another IPR. Cost-driven complementarities may, instead, result from a more effective use of inputs which are common to the management of different IPRs; for instance, the expertise of attorneys or IP-experienced staff can be leveraged across several IPRs, thus generating scale and scope economies.

Llerena and Millot (2013) present a game-theoretic model which encompasses the possibility of both complementarity and substitutability between patents and trademarks. The relation between these two IPRs is a dynamic one: while patent protection is in place, competition is prevented and therefore a trademark is of little use (patents and trademarks are substitutes). On the opposite, once the patent expires, the trademark turns out to have a crucial role allowing the firm to benefit from the goodwill built while the patent was in force (patents and trademarks are complements). Llerena and Millot show that, overall, whether patents and trademarks are substitutes or complements crucially depends on the length of the product life-cycle and on the intensity of advertising spillovers (i.e. the extent to which rivals benefit from the investment in advertising of the innovator). With a short-lived product, patent protection alone allows the firm to fully appropriate the value of its product, hence the substitution effect prevails. Alternatively, if advertising spillovers are large, trademark is essential for the firm being able to capture the returns from its product once the patent has expired; in this case, the two IPRs are complements.

Empirical evidence on IP bundles

An appropriate analysis of IP bundles would require information on the use of different IP rights for the same product; unfortunately, with very few exceptions, the lack of product-level information has prevented researchers from conducting a thorough examination of IP bundles. Much of the existing literature is performed at the firm-level and, therefore, it cannot disentangle whether firms use two or more IP rights to protect the same or different products.

Helmers and Schautschick (2013) provide a comprehensive study on IP bundles (registered design rights, patents and trademarks) in UK, by combining both firm- and product-level data. The firm-level investigation is conducted using the full sample of registered firms in the UK over the period 2002-2009; the main evidence is that UK firms holding both patents and trademarks account for a sizeable share of total assets, employment and turnover in the manufacturing sectors. Figure 4 goes more into the details at a sectorial level measuring the weight (within the industry and on the whole UK economy) of firms owning both trademarks and patents; the weight is measured in terms of total assets, employment and turnover and it is represented on a 0-10 scale.

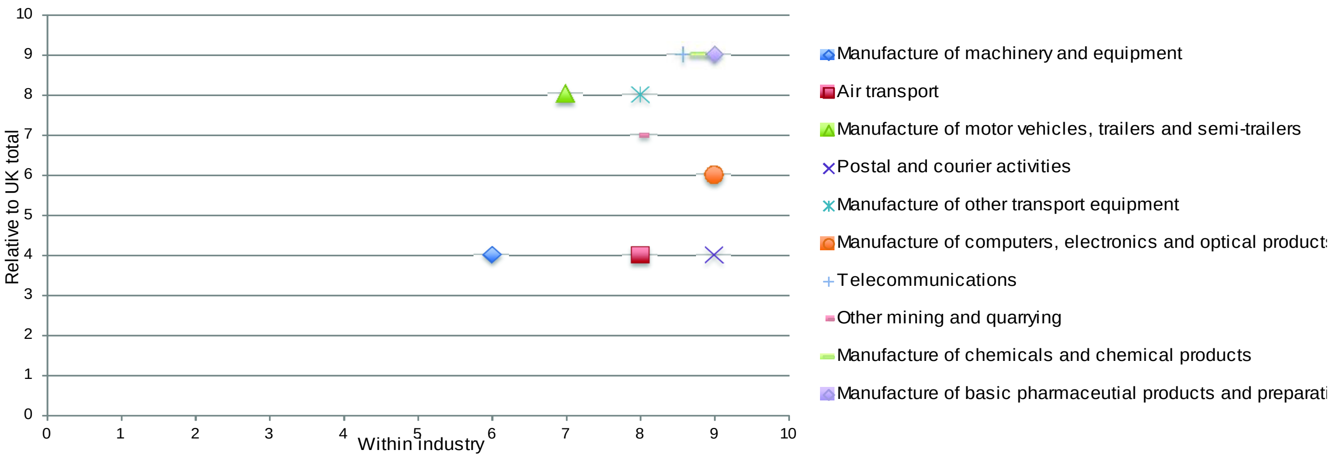

Figure 4: rankings of the importance of firms holding patents and trademarks (Source: Helmers and Schautschick, 2013)

The figure shows the top 10 sectors in terms of importance of use of IP bundles. It emerges that the joint use of IP rights is particularly significant in “Manufacture of basic pharmaceutical products and preparations”, and “Manufacture of chemicals and chemical products”. Within the ICT sectors, the joint use of patents and trademarks is important in “Telecommunications” and in “Manufacture of computer, electronic and optical products”.

From the above evidence, the strategy of combining patents with trademarks appears as very common among UK firms, thus suggesting that IP bundles are a widespread phenomenon. Nevertheless, Helmers and Schautschick (2013) reach a substantially different conclusion when conducting a more appropriate product-level analysis. In the second part of their study, the authors restrict their attention to a sample of UK firms;[34] for these companies, they gather information both on IPR holdings (patent, trademarks and registered designs) as well as on products. In this way, the authors associate the different IPRs to the product they refer to and are able to

[34] They consider firms holding less than 5 patents and trademarks.

distinguish between firms truly employing IP bundles and firms that use different IPRs but not to protect the same product.

This product-level analysis reveals that most firms using different IPRs do not combine them as bundles: the average share of companies using bundles across all industries is only 0.6%, and even within the manufacturing sectors the share is only 1.3%. The share of firms using both, patents and trademarks – although not as a bundle – is 7% across all industries and 10% for the manufacturing sectors.

Other empirical evidence on IP bundles which deserves to be highlighted is presented in the already mentioned papers by Graham and Somaya (2006) and Llerena and Millot (2013). As discussed, these two papers essentially study whether formal IPRs are substitutes or complements and, as such, they are related to IP bundles. Graham and Somaya (2006) focus on the US software industry and use data on copyright and trademark litigation cases. Once controlled for a series of firms characteristics, they find that the residuals in the copyright and trademark litigation rates are correlated. The two authors interpret these findings as an evidence of the complementarity between trademarks and copyright.

Llerena and Millot (2013) test the predictions of their game-theoretic model using information on the IP activity of 785 French firms. Their estimations provide only weak evidence to the hypothesis of patents and trademarks acting as complements, although the authors find interesting differences across industries. More specifically, patents and trademarks appear to be used as complements in pharmaceuticals and as substitutes in the computer and electrical equipment industry. In line with the predictions of the theoretical model, this evidence suggests that in industrial sectors with short-lived products, like ICTs, rather than being employed in bundles, patents and trademarks are used as substitutes. Nonetheless this evidence must be taken with caution as the authors use firm rather than product-level data to conduct their investigation.

To conclude, the joint use of IPRs is certainly an intriguing issue particularly in ICTs where short product life-cycle, strong competition, high product complexity require firms using effective protection mechanisms. The literature on IP bundles is scant and further research is needed to shed light on these issues.

6. IPRs in the software industry

Software is certainly among the most important ICT products; embedded in almost every technology in our life, software is an essential factor and a major driver of the global economy. Together with hardware, software represents the backbone technology enabling the development of the Digital Single Market, one of the priorities of the European Commission. The growing importance of computer programs has made it urgent the need to determine the best form of protection of intellectual property in software.

In the early days of the software industry, computer programs were not a patentable subject matter; companies did not consider software as a product *per se* but they used to sell it bundled with hardware. Since the late 70s, with the advent of personal computers, software development was gradually separated from hardware production and companies, especially in the US, put growing pressure to consider software a patentable subject matter. After a series of Court decisions, in the US the patentability of computer programs has broadened and since the mid 80s a growing number of software patents has been issued.[35]

[35] In the 1981 decision Diamond *vs* Diehr, the Supreme Court established that an invention embedding a computer program could be patented. Software has been considered as any other invention since 1994 when the Court of Appeals for the Federal Circuit ruled that software running on general purpose

In Europe software is protected by copyright while it is not patentable "as such". However, as we detail below, embedded software, or computer-implemented inventions (CIIs) in the technical jargon, can be patented.

In the last 20 years discussions about the role of IPRs in software have also been fuelled by the success of open source software (OSS). Based on an alternative way to protect innovation known as "copyleft", OSS calls into question the traditional role of IPRs as mechanisms to promote computer programs innovation.

<u>Software patents: legal issues in EU and US</u>

As mentioned above, the US and the EU have followed two different approaches regarding the patentability of software. In Europe, Article 52, paragraph 2 of the European Patent Convention (EPC) excludes "programs for computers" from patentability. Nonetheless, several patents issued by European patent offices and by the EPO are software-related. While this may appear to be contradictory, it is the result of the subsequent paragraph of Article 52 of the EPC which states that computer programs are banned from patentability "only to the extent" that a patent application relates to this subject-matter or activities "as such".

In other words, the exclusion of computer programs from patentability is limited to software applications *per-se* but it is not necessarily applicable to programs introducing technological innovations. Historically, patentability of computer programs in Europe can be traced back to 1986 when the EPO Technical Board of Appeal ruled that a patent could be granted to a method of digitally processing images using a computer.[36] Although examiners initially rejected the application on the grounds that it was a computer program, the Board of Appeal overturned the decision concluding that an invention implemented by means of a computer program may be patentable as long as it represents an improvement of the state of art. With this decision the Board of Appeal paved the way for what has become known as the requirement for a "technical effect"; since then several other rulings moved in the same direction[37] and today it is generally accepted by European patent offices that a computer-implemented invention solving a technical problem in a novel and non-obvious manner can be patented (EPO, 2014).

The question, therefore, is whether a computer program provides a solution to a technical problem. According to the jurisprudence, the technical effect can be either external or internal to the computer itself; for example, the technical effect can be a reduced access time to the computer's memory or an enhanced user interface (internal effects) or it can be an increase in the efficiency of an external device or an improvement in the interoperability of different equipment (external effects).

In the US, by contrast, there is no statutory exclusion from patenting of computer programs. Software related-inventions are treated as no different to inventions in any other technological field; this pro-software patent regime has led to an exponential growth in the number of patents granted by the USPTO. Nonetheless, some recent rulings are slightly changing the scene and today it is more difficult to obtain patent protection for software applications.[38]

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computers is patentable (in re Alappat case). This decision paved the way for the patenting of software and established that computer programs are something more than mere mathematical formulas.

36 See EPO decision T208/84M, known as the Vicom case.

37 For a discussion of the main EPO's decisions, see Archontopoulos (2011).

38 Up to 2008, the claimed invention had to produce a "useful, concrete and tangible result" in order to obtain protection in the US. In 2008, a landmark decision of the Court of Appeals for the Federal Circuit has established new guidelines for patent-eligibility (the Bilsky case); the evaluation of a "useful, concrete and tangible result" has been set aside in favour of a "machine-or transformation test", which imparts additional physicality requirements on method claims. This change has made it more difficult to obtain protection for some forms of applications, particularly those where computer implementation would be generally irrelevant, or at most incidental. In 2012, the US Supreme Court has partially changed the

6.1 The innovation process in software

In order to better understand the debate about the role of different IPRs in computer programs, it is useful to remind the main characteristics of software production: i) cumulativeness of the innovation process, ii) short product life-cycles and iii) high level of abstraction.

Innovation in the software industry is highly cumulative and a common practice in the development of new computer programs is code re-use. Just to take a relevant example, Internet Tablet, an operating system for mobile phones developed by Nokia and installed in the N800 series, includes lines of code of several existing programs such as Linux, X-Window, GNOME, and BlueZ. It has been estimated that the source code of Internet Tablet is made of more than ten million lines and that about 85% of them are taken from existing programs while only 15% have been actually developed or modified by Nokia. Another interesting example is Darwin, the core program of Apple's MAC OS X operating system. Darwin is made of more than seventeen million lines of code, most of which are taken from open source applications such as NetBSD, OpenBSD, FreeBSD (Comino and Manenti, 2014).

A second important characteristic of software relates to its short product life-cycles. As a matter of fact, most programs become obsolete in only a few years and are quickly replaced by new applications. In this extremely dynamic environment, it is the advantage of being the first mover that allows the innovator to collect most of the returns generated by a new application.

Another characteristic of software relates to the high level of abstraction characterising the underlying technology (Bessen and Meurer, 2008). Software algorithms can be represented in several different ways; at the same time, two apparently different algorithms may turn out to be equivalent. Bessen and Meurer (2008) discuss the example of the "traveling-salesman" algorithm for routing delivery trucks; some time after its development, this algorithm was found to be equivalent to another algorithm used to solve the map-colouring problem, a quite different purpose in practice. Abstraction of software technology makes it extremely difficult to know whether a given invention is truly different from previous ones. As we will see below, in this context, patent protection may be problematic as it might be difficult to ascertain whether a new software program is infringing a protected technology.

6.2 Empirical evidence on the use of different IPRs in software

The empirical literature on the use of different types of IPRs in software is relatively scant. Blind (2007) presents a study of IP strategies of German software producers. Based on a survey on 280 companies in the year 2000, the author finds that the most common mechanisms used to protect software innovation were internal confidentiality (secrecy agreements with employees), lead time, and customer relations management. Trademarks, copyright and patents were less important, even though significant differences emerged between companies focusing only on the development of software and companies also involved in activities of the manufacturing sector (mainly machinery). Trademarks were utilised by a significantly larger share of companies belonging to the former group (63.4% compared with 43.3%). By contrast, patents were most commonly used by companies active also in other sectors; in this case the percentages were 15.9% (companies producing software only) and 34.6% (companies also active in other sectors). The second part of the study focuses on companies active only in software development. The author compares data from the 2000 survey with a novel set of information resulting from the 2004 Community

decision of the Federal Circuit; the Supreme Court did not completely throw out this test as it established that this is not the sole test for determining patent eligibility for processes. More recently, in 2014, the US Supreme Court declared that a software package for electronic escrow service for facilitating financial transactions was ineligible for patent protection (Alice Corp. vs CLS Bank International case). These decisions increased uncertainty about the patentability of computer programs in the US.

Innovation Survey. This comparison is particularly meaningful provided that during those years a lively discussion on the patentability of software was ongoing. Even though the percentage of firms actually applying for patents did not change over time (it was 15% both in the year 2000 as well as in the year 2004) the share of firms assessing patents as being important to protect their inventions doubled from about 35% to slightly less than 70%. As a matter of fact, in the year 2004, the importance of patents was considered just below that of internal confidentiality and not far from lead time. In a similar study based on a sample of US technological start-ups (the Berkeley Patent Survey), Graham, et al. (2009) find that software firms tend to patent less than companies in other high-tech sectors and do not consider patents as an effective mechanism to protect innovations.

Despite software-producing firms consider other mechanisms more effective than patents to protect their innovations, software patenting is numerically an extremely important phenomenon. Estimating the actual number of software patents is a complex matter. Computer Implemented Inventions (CIIs) are embedded into technological systems potentially belonging to any industrial area; therefore, in order to assess the exact magnitude of software patenting, researchers usually resort to keywords searches in the application documents. This is what has been done in a recent discussion paper by the research organization Fraunhofer/4iP which looks at CIIs applied for at the European patent office (Fraunhofer/4iP, 2015). By running keywords searches in the title, abstract and claims of each patent application, the authors estimate that, for the year 2010, the number of CII applications were about 44 thousand, which represented a share of 33% of the overall number of filings; therefore, about one out of three applications at EPO is intended to protect a computer-implemented invention.[39]

Looking at the number of filings by industrial areas, the authors notice that CII filings are not limited to the software industry; about 78% of CIIs in Europe are filed within the manufacturing sectors, particularly in "Computer, electronic and optical products" and "Machinery and equipment n.e.c.". This is further evidence that CII patents play a major role outside the software industry. Fraunhofer/4iP (2015) also observe that, in Europe, a significant share of CII applications is filed by SMEs. Nonetheless, this share is smaller than when the total number of applications filed at EPO is considered; this fact signals a higher level of concentration of software patenting among large enterprises (LE in Figure 5). Comparing Europe with the US, Fraunhofer/4iP (2015) show that the share of CII patents belonging to SMEs is larger in Europe. This finding is in line with previous evidence showing that in the US the patenting activity in the software industry is concentrated in the hands of few large companies (Bessen, 2011). Consequently, it seems that the vast majority of software firms gains little benefit from software patents.

[39] The authors also provide evidence for the US and find that, in 2010, 95,000 filings regarded CIIs (31% of the overall number of applications). These figures are not directly comparable with those reported for the EPO. For the US patent office the keywords search is limited to the title and abstract of the application (not considering the claims) and therefore it tends to underestimate the extent of US software-patents. Applying the "USPTO methodology" to the European data, Fraunhofer/4iP (2015) find that in the year 2010 the number of CII applications at the EPO reduces to about 30,000 (23% of the overall number of applications).

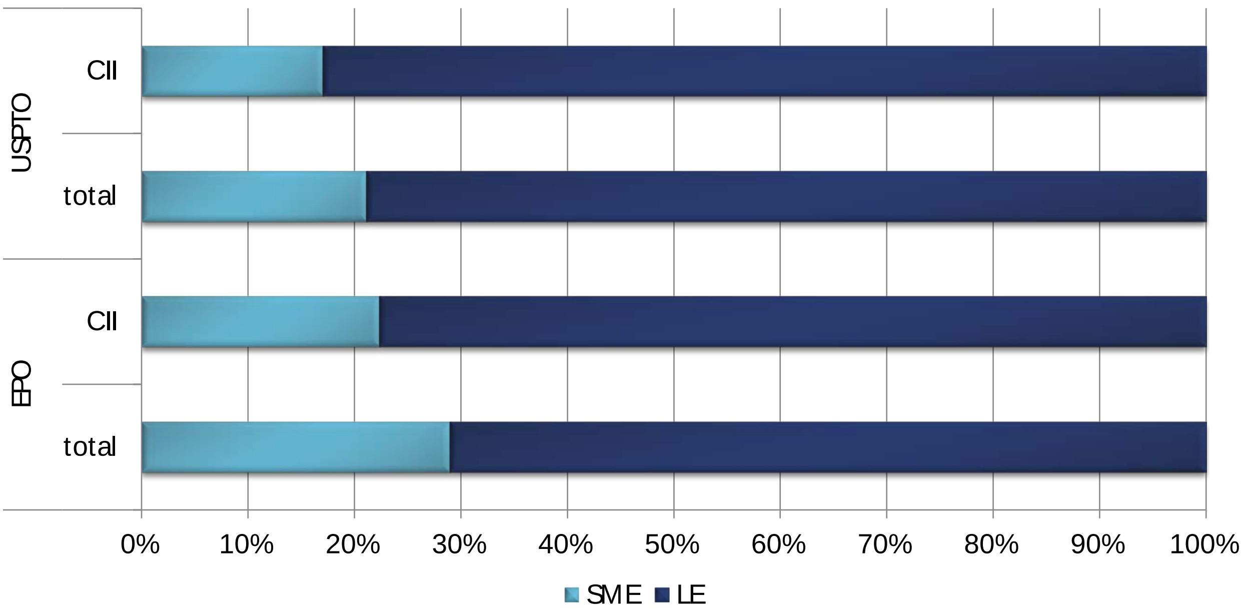

Figure 5: shares of SME/LE filings in total filings by companies, 2010 (Source: Fraunhofer/4iP, 2015)

Given its nature and characteristics, a software-related innovation can be protected by means of several IP rights. As we have already discussed, Graham and Somaya (2006) find that software companies use bundles of copyright and trademarks to protect their inventions; this finding suggests that software firm exploit complementarities among different IPRs. Unfortunately the empirical literature on the diffusion of IP bundles in software is extremely limited so that it is not possible to fully evaluate the extent to which companies employ several IPRs to protect the same product.

<u>Software patents: what can we learn from the US experience?</u>

Since the year 2000, European governments are discussing about the opportunity to strengthen patent protection on software related inventions.[40] The debate is inevitably affected by the experience in the US where software is more easily liable to patent protection.

The supporters of software patents take the moves from the observation that the US are the undisputed leaders in the software industry; this leadership, they claim, has emerged also because of a robust patent system protecting computer implemented innovations. According to this view, patents have significantly contributed to software innovation and, in contrast with the common criticism, US software patents are of comparable quality of patents in other technological fields.

Several scholars have investigated the quality of software patents in the US and they have often reached conflicting results.[41] Allison and Mann (2007) proxy patent quality with the number of prior art references, claims and citations; using this methodology they measure the quality of nearly 35,000 software patents held by the firms listed in a leading industry periodical during the five-

40 A heated debate developed on the draft "EU Directive on the Patentability of Computer-Implemented Inventions", proposed by the European Commission in 2002. The proposal was highly controversial; opponents claimed that it would have dismantled the more stringent restrictions against software patenting thus leading to an increased assertion of patents on software across the EU. After several years of discussion, the proposal was rejected on July 2005.

41 As discussed above, there is no agreed definition of patent quality. EPO (2012a) suggests that it should be measured in terms of the ability of a patent to satisfy the statutory patentability requirements and to leave little doubt about its boundaries.

year period from 1998-2002. They find that software patents awarded to computer technology firms have more prior art references, claims, and forward citations than the patents that the same firms obtain for non-software inventions. On top of this, they also find that the patents of firms producing only software are of higher quality than software patents obtained by firms which are also active in other product lines.[42]

These findings are challenged by Miller (2012). Rather than pointing to the number of claims and prior art, Miller looks at claims' validity. The author collects information on patent lawsuits filed in the US from 2000 to 2006 and shows that software and business methods patents, which are typically software patents as well, are more likely to have invalid claims, that is at least one claim that is non-novel or obvious. Miller's evidence is in contrast with previous studies and casts doubts on the alleged quality of the software patents issued by the USPTO. James Bessen, one of the fiercest opponents of patents in software, interprets Miller's results as one of the effects of the high level of abstraction of software patents which, as discussed above, makes it more difficult to examiners to ascertain whether a technology is truly different from existing ones (see Bessen, 2014). According to Bessen, in the presence of extremely abstract technologies it is almost inevitable for Patent Offices to issue patents with invalid claims.

Still following the arguments in Bessen (2014), patent abstractness would also be one of the root causes of the recent growth in lawsuits involving patents in software and in business methods. According to GAO (2013), in the period 2007-2011 more than 46% of the US lawsuits involved software-related patents. As shown in Figure 6, the number of lawsuits involving software-related patents has been steadily increasing since 2008 and it has overtaken the number of lawsuits that do not involve software-related patents in 2010 and 2011.

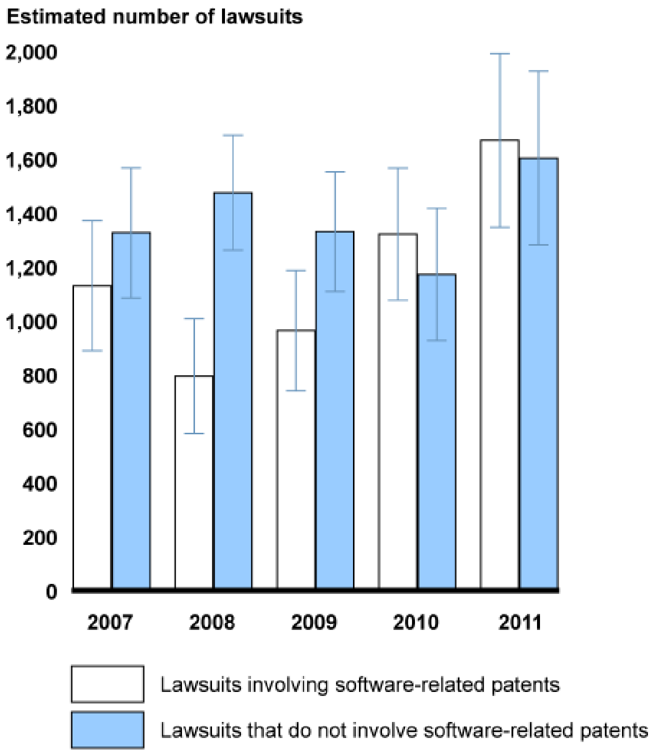

Figure 6: estimated number of patent infringement lawsuits (Source: GAO, 2013)

[42] Similar evidence is in Hunter (2003).

Following to Bessen (2014), the high degree of litigation of software-related patents is due to the fact that it's often not clear what these patents actually cover. This argument is confirmed in Miller (2014); the author shows that in the period January 2002 – December 2012 the Court of Appeals for the Federal Circuit reversed the decision of the District Court judge on software patents 40% of the times; this only happened 24% of the times with other patents, thus providing evidence that software patents have "fuzzy" boundaries yielding high litigation rates.

Bessen (2014) also highlights how the unclear boundaries of software patents may have the undesirable consequence of stimulating lawsuits from PAEs; as seen above, usually these entities do not make any useful products on their own but profit from suing other companies. Often innovators believe that they have not infringed any existing patent, but if Courts can reinterpret the patent in a way that it covers a broader range of technologies, innovators may find themselves inadvertently infringing the patent. On top of this, most of these lawsuits are against small firms, thus exacerbating the negative effects of PAEs on new entrants.[43]

6.3 Open source software

In the recent years, the traditional view of IP rights in software has been challenged by the emergence of open source software (OSS). What makes OSS different from traditional proprietary software is the fact that the source code (namely, the underlying programming code) is made available for using, reading, changing it or developing further versions of the program. The aim of these provisions, generally referred to as "copyleft", is to keep the software source code open, thus promoting access, diffusion and collaborative development (sharing and re-use) of programs. This is in contrast with the traditional use of IP rights in proprietary software where patents and copyright protect developers from unauthorized copying or selling of their work. Additional protection is also guaranteed by the fact that proprietary software is usually distributed in executable format which is unreadable and unmodifiable by humans.

In order to be defined as open source, a software must be distributed according to a license meeting the following three conditions: *i)* the program must include the source code of the software, *ii)* the license must allow the licensee to modify the code and to develop derived works, *iii)* the license shall not restrict any party from selling or giving the software away.[44]

The OSS mode of production is based on the collaboration between independent developers. The Internet has facilitated the development of software programs among a great number of dispersed user-programmers who coordinate their activities and share their efforts online. Even if precise figures on the diffusion of ISS are not available, in several market segments open source products have gained leading positions. Probably, the best-known open source software is Linux; in September 2014, worldwide Linux users were estimated to be more than 73 million, with a market share of nearly 20% in the servers segment (see LinuxCounterSite). Through its distribution Ubuntu, Linux is also making inroads into the desktop market and it is also becoming a strong player in the mobile segment with the operating system Android which is based on the Linux kernel. The Internet browser Firefox is another prominent example of successful open source software; according to several estimates, Firefox is the second most used browser after Google Chrome, with nearly 20% of the market (http://gs.statcounter.com/). Another segment where OSS plays an important role is cloud computing, namely the use of computing resources (hardware and software) available in a remote location and accessible over the Internet. While the market is dominated by proprietary cloud service vendors, open source technologies drive innovation in cloud computing technologies; as a matter of fact, several proprietary applications run on open source cloud computing platforms (Pentheroudakis, 2015).

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[43] Fuzzy boundaries are not unique to software. Patents on mechanical devices or other technologies can also be written in vague language and this often cause lawsuits too.

[44] Note that the three conditions do not necessarily imply that the software needs to be released for free.

But the true sign of the success of OSS lies in the number of developers which around the world are actively contributing to the development of new open source projects. As of April 2015, SourceForge.net, the most important web-based open source projects repository, hosts more than 430,000 projects and has more than 3.7 million registered users.

Several scholars argue that the very existence of OSS and of its success contradict the conventional wisdom according to which the main driver for innovation is the prospect of future returns obtained thanks to copyright and patent protection. Hence, one of the main issues concerning OSS regards the incentives to innovate. In other words, the question is: why do bright, skilled, in many cases unpaid, developers contribute to open source projects?

Several survey studies have analysed the reasons to contribute to open source projects (see Ghosh et al., 2002 and Lakhani and Wolf, 2005 among others). An important distinction made in this literature is between intrinsic and extrinsic motivations: extrinsic motivations are instrumental in nature and are related to extrinsic rewards, as improvement of programming skills, creation of, otherwise unavailable, code, enhancement of professional status. Intrinsic motivations are related to individual satisfactions and include motivations such as altruism, fun, reciprocity and intellectual enjoyment. Lakhani and Wolf (2005) find that the most common motivation is extrinsic (creation of, otherwise unavailable, code) followed by an intrinsic one (OSS as intellectual stimulus).

Open source and business

The OSS production model has proved so effective and cost efficient that both large incumbents as well as small start-ups are increasingly adopting business models based on open source strategies. The decision to develop an open source software may be based on the possibility of re-using existing lines of code, thus substantially reducing the time and costs required for software completion. Network externalities may be another explanation for the adoption of open source strategies; firms may choose to release their software as open source to stimulate its adoption. The firm can then derive profits by selling other (hardware or software) products which are compatible with the industry standard (Comino and Manenti, 2014).

Daffara (2009) describes the major business models adopted by OSS firms. The author examines over 200 European software houses which have adopted open source strategies and investigates which business models are the most common. The author finds that selling complementary services is the most widely adopted business model; in most cases, firms create the software, release it under open source licenses and profit from selling training, consulting and customisation services. Another popular business model is the sale of complementary products: nearly 20% of the firms in the sample earn profits by selling hardware products which make use of the open source software. Other common open source business models are open core and dual licensing, two forms of versioning strategies. In the first case, the firm releases the core version of the program for free under an open source license, and profits from the sales of upgraded versions of the software combining the core program and some additional functionalities. In the case of dual licensing, there is only one version of the software which is distributed under two different licensing schemes: an open source and a proprietary one (see Comino and Manenti, 2011)

Firms often employ hybrid models releasing some of their applications under open source licensing terms and others under proprietary licensing agreements. Bonaccorsi et al. (2006) analyse a sample of nearly 800 European software firms and find that more than 25% employs a hybrid approach. The authors classify firms according to their age and degree of openness (from "only proprietary" to "only OS" firms) and find that young and small-sized firms are those that are more OS oriented.

OSS and patents

In March 2003, the company SCO group, a proprietary software developer of UNIX-related products, initiated a series of legal controversies against Linux vendors and users, including IBM, Red Hat and Novel, claiming that these firms were infringing upon its intellectual property.

The lawsuit against IBM is probably the most well-known among practitioners; SCO alleged that by donating source code to Linux, IBM was violating SCO's property rights on the UNIX kernel.

Since the SCO-Linux controversies, not only big companies adopting OSS solutions but also small developers have been increasingly involved in patent litigations. For example, in 2011, Lodsys LLC sent letters to a number of small open source mobile application developers claiming that their software were infringing on its patents. Lodsys LLC legal actions proved to be quite successful as it managed to collect over one hundred licensees in pre-litigation settlements (see Burns, 2013).

For these reasons, and despite the OSS community's general aversion to software patents, OSS developers started adopting defensive strategies against unwarranted assertion of patents. Following Burns (2013), among such strategies there are: *i)* patent peace provisions, according to which the licensee of an OSS program forgoes any patent lawsuit against the licensor, *ii)* publishing or republishing code in order to create documentation easily accessible to the patent office thus serving as invalidating prior art against future patent applications and, *iii)* creation of patent protection groups, where firms pool their IP resources for the primary purpose of patent defence. This latter strategy represents a typical example of defensive patent pool. The most prominent example is Open Invention Network (OIN) which was launched in 2005 with the mission to protect Linux. This defensive patent pool is backed from some major ICT players such as Google, IBM, Philips, Red Hat, Sony, NEC, Novel and dozens of other large and small organizations. OIN owns around three hundred patents which are made available free of charge to any company or individual that agrees not to assert its patent against the Linux system (see Burns, 2013).

<u>OS beyond software</u>

An interesting question regards the possibility of exporting the open source model to other sectors. Natural candidates for a possible adoption of this model are information goods. More specifically, Maurer and Scotchmer (2006) observe that because of their high information content, the two technologies where the open source model has flourished are online reference works (e.g. Wikipedia) and geographic information systems.[45]

Penin (2009) addresses the issue of the exportability of the open source model beyond information products. Interestingly, the author suggests that open source may be especially promising when aimed at creating an upstream open knowledge platform into which firms can tap in order to develop downstream applications. An example of a non-software open source innovation project is Biological Open Source (BiOS). BiOS is an open and collaborative research in agronomics; it is a platform providing research tools for the development of downstream proprietary applications such as new drugs or new crops, and for this reason it is very important that such tools remain easily accessible for reuse. Interestingly, Penin (2009) highlights how despite being an open source project, BiOS heavily relies on patents; indeed, BiOS has formed a patent pool and agrees to grant non-exclusive licenses only to those who accept the viral terms of the BiOS license. Virality implies that, in order to use the technologies patented by BiOS, a third party has to agree to grant-back any improvements and modifications into the open patent pool. BiOS is an interesting example of how traditional IPRs can be used to develop and promote an open source innovation project.

6.4 IPRs in mobile applications

The market for mobile applications is undoubtedly the most dynamic and innovative segment in today's software industry. In December 2014, more than 3 million apps were available on the

[45] The Internet is full of high quality wikis and blogs where volunteers exchange and organise information. Peer review tests of the Wikipedia on-line encyclopedia suggested that its accuracy is comparable to that of Britannica. Also in Geographic Information Systems open source methods have acquired a foothold. The technology is highly computerised and depends on users to notice and correct errors in mapping data (Maurer and Scotchmer, 2006).

various stores which include Apple's iTunes, Android's Google Play and Microsoft's Windows Store. Looking at iTunes only, in 2014 the number of apps has grown nearly 60%, from 890 thousand available apps on 1/1/2014 to over 1.42 million on 12/31/2014 (www.adjust.com). The growth in the number of available apps has been accompanied by an exponential increase in downloads. According to Statista.com, the cumulative number of apps downloaded from iTunes from July 2008 to October 2014 was about 85 billion. Also in terms of the number of developers and publishers involved in the app market, figures are quite impressive: according to Priori (2014), in February 2014 more than 600 thousand developers published at least one app on iTunes or Google Play, with an increase of nearly 10% with respect to the previous month.

By looking at the price paid by large incumbents for the acquisition of new apps it is possible to ascertain that the innovation generated in app markets is also extremely valuable; just to take three relevant examples, Facebook bought Instagram for $1 billion, Google acquired the Sparrow email app for $25 million and the Japanese social gaming company DeNA purchased for $400 million the game developer *ngmoco:)* (Kraaijenzank, 2013).

According to the traditional view on IPRs, this considerable amount of innovation would have to be accompanied by a substantial protection of intellectual property. The evidence collected by Kraaijenzank (2013) does not confirm this assertion. The author uses detailed app-level data from all major app stores to investigate the role of patents in the app markets. As a matter of fact, apps often contain subject matter that is patentable, especially in the US; however, Kraaijenzank (2013) finds that the largest share of app developers do not rely on patents to protect their apps.[46] Instead, lead time is found to be the main instrument to appropriate returns from inventions.

A possible explanation for this evidence is offered by James and Arkley (2012). The two authors argue that copyright and patents are ill-suited to protect apps. Consider patent protection: app functionalities can be protected with patents, at least in the US, if they are novel. Nonetheless registration takes time, in the meantime the app value declines and the technology might have moved on. On the other hand, copyright which protects app design (text, images, sounds and videos) arises automatically. Nevertheless it requires the developer to prove ownership and a causal connection between the source work and the infringing work, which may be very difficult to demonstrate.

At the same time, despite the high rate of innovation, these markets also experience a huge amount of imitation. The industry analyst *Trend Micro* has revealed that in July 2014 nearly 900 thousand Android Apps were cloned. App developers are increasingly concerned by imitation but traditional protection mechanisms do not seem to be suited to this dynamic environment. All in all, we can conclude by saying that app markets represent a very effective example of a segment characterised by impressive innovation rates without formal IP protection and with substantial imitation.

7. Policy implications and perspectives for future research

According to the findings of two large-scale surveys recently conducted by EPO and OHIM, IPR-intensive companies generate more revenues per employee, pay higher wages and contribute to a large portion of the European GDP (EPO and OHIM, 2013 and OHIM, 2015). The scope of this report has been to provide a comprehensive and unitary analysis on the use of patents, copyright and trademarks in Information and Communication Technology (ICT) industries. ICTs are among the most dynamic and innovative segments of modern economies and they are very intensive in the use of IPRs. In the literature, the roles of patents, copyright and trademarks are usually

[46] The author finds that patent protection is used mostly for apps that involve technologies on digital data transmission, an area where patent protection is deemed as essential for strategic reasons.

investigated separately; to the best of our knowledge, this is one of the few studies offering a joint perspective to the use of different formal IPRs.

The unitary perspective is useful in order to discuss the overall functioning of the current IPR-system and to highlight the main challenges faced in the specific context of ICTs; in addition, the joint analysis of the various formal IPRs also allows us to identify some promising areas for future research.

The surge in patents and thickets require the definition of solutions able to deal with technology fragmentation. As regards pools and SSOs, the traditional institutions created by market participants to address fragmentation and interoperability issues, there is the need to better frame the licensing rules governing the interactions among patent holders. A major role in dealing with technology fragmentation is going to be played by the market for ideas and by patent intermediaries. In recent years, patent-related transactions have increased in importance despite search costs and information asymmetries limit the scope for technology markets. Intermediaries may contribute substantially to improve the efficiency of these markets but in some cases their activities generate concerns. For example, patent assertion entities make markets more liquid but they also have the adverse effect of stimulating lawsuits. The available evidence on patent intermediaries is almost exclusively US-based. Further empirical investigation on Europe is necessary.

The surge in patenting also raises concerns about patent quality. A decline in quality increases transaction and litigation costs, thus endangering the functioning of the patent system as a whole. For this reason there is a general consensus that the European patent offices should exert efforts in order to maintain and possibly increase the quality of the patents they grant. The new unitary patent system that EU countries are about to adopt is expected to have a strong impact. This will raise interesting research and policy issues. As a matter of fact, there is the fear that the new system, intended to reduce patenting and enforcement costs and to harmonise EU legislations, may also stimulate PAEs' activities.

Section 3 of the report focusses on copyright and on the effects of digitisation and file-sharing systems. Most of the contributions in this field look at the music industry. File sharing technologies undoubtedly hamper copyright protection; however, the available evidence does not indicate that these technologies have lowered the incentives to create artistic works. Digital technologies make it extremely easy to combine existing content in order to develop new artistic works and services. In this context, it is particularly urgent to create an efficient market for copyright licensing. The simplification of pan-European licensing for copyrighted works is also one of the pillars for the establishment of the Digital Single Market in the European Union.

The literature on trademarks and IP bundles is relative scarce and typically not specific to information and communication technology industries. In our view, the joint use of IPRs (bundles) is one of the most intriguing issues in ICTs where short product life-cycle, fierce competition and high product complexity require firms to use effective protection mechanisms. A better understanding of the interplay of the various IPRs is also important for policy makers. Further research in this field is highly desirable.

The final section of the report is devoted to analysing more in details software, an interesting industry to focus on also because of the growing importance of open source. Software patentability is one of the major issues discussed both in Europe and in the US. Several different features of computer programs make patents unfit to protect software innovation (short product life-cycles, cumulativeness of the innovation processes, high level of abstraction of software algorithms). Opponents of software patents argue that they are inevitably of low quality. This view is supported by evidence showing that software patents are more likely to include invalid claims and to be litigated in Courts. These conclusions are mainly drawn from US patent data; further investigations on European software patents would be very welcomed.

One of the most interesting phenomena in the software industry is open source. A series of legal controversies against Linux vendors and users has raised concerns about the compatibility and coexistence of patent protected software and open source. For these reasons, open source developers started adopting defensive strategies as the creation of patent pools aimed at protecting Linux.

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