Patent Litigations as a Barrier to Innovation: The Case of Light Emitting Diodes

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Abstract

This paper is concerned with innovation dynamics in the LED sector, which is one of the fastest growing technological domains today. In the most general sense, the paper is concerned with barriers to innovation in the LED sector. More specifically, our emphasis is placed on the current property rights regime that can act as a barrier to innovation in the industry. The reason that this may be so is evident in the dynamics of the LED industry today; a fast growing, complex and interdependent knowledge base, accompanied by a significant amount of patent lawsuits, where incumbent firms thrive to establish their proprietary standards to win the majority of the market. While such developments characterise the growth phase of many technologies, they can come at the expense of reducing variety and driving out small and creative enterprises that may not have the resources and market capabilities to participate in the innovation process, especially in terms of ecoinnovations. To explore these issues, we carry out a patent analysis in LEDs between 1980 and 2010, to reveal the extent to which patents subject to lawsuits are significantly different from the rest of LEDs patents. Our results indicate that in terms of their scientific basis, and of the extent to which later inventions draw upon them, litigated patents are significantly more valuable. This has two implications. First, as far as LEDs are concerned, lawsuits are driven by technological concerns rather than being solely a strategic or political tool used by incumbent firms. Second, because these patents can be the drivers of inventions in an increasing number of areas, caution is required at policy level to strike a fair balance between the protection of innovations on one hand, and maintaining variety which mainly comes from small and innovative firms on the other.

1. Introduction

During the recent decades the lighting industry has been going through a radical transition ranging from incandescent technologies to energy efficient LED (light emitting diode) systems. LEDs are today widely used in a variety of areas, and accordingly technological change has been fast with the contribution of a variety of actors such as universities and research labs; private companies, market and standardization bodies being the most prominent ones. As expected in any growing technological field, LEDs also seem to have witnessed their share of standards wars, as evident in many consortia build around sponsoring the standards of a few powerful actors. Not surprisingly, technological wars are also evident when looking at the strong increase in the number of patent litigations in the field. Although the technological and environmental performances of LEDs are highly superior to former lighting technologies, large improvements remain to be done especially in terms of toxicity, lifespan and recyclability. Since such improvements will come at a cost they will face barriers on their path to become the dominant technology of the future lighting regime. In order to support the sustainability transition of the latter, it is thus paramount to identify and address the barriers to innovation in the LED sector. Among the many obstacles to innovation introduced in the next section, in this paper we investigate the role of patent litigations in deterring LED firms from ecoinnovating.

While much has been written about the extent to which patenting systems in general, or patent litigations in particular, deter firms from participating in the innovation process, discussions have usually focused on legal and institutional levels. In this paper, we are interested in the technological dimension of litigations. In particular, we address the following question: do litigated patents differ in terms of their scientific and technological characteristics from other patents in the industry? This question is important in two related ways, from both a technological and policy perspective.

From a technological point of view, we draw upon theories of innovation to claim that in the evolution of technologies, certain inventions have a stronger potential to open up new paths for further inventions. These technologies are particularly important, because many inventions which follow them build upon them, thus contributing to the process of variety generation, which further enhances innovation through recombination. Especially in periods of rapid technological change, where variety generation and participation by many firms is at its peak, the extent to which patents subjected to litigation are technologically important is likely to enhance an atmosphere of innovation deterrence, both in terms of innovation and of entry in the sector by young and creative firms. This brings forth the second way in which this question is important. Recently an important debate has emerged at the policy level about the extent to which patent systems deterred innovation in certain technological areas. For example, while in the case of technologies like pharmaceuticals and biotechnology, where research and development costs are too high and have to be covered before the patent expires, it is not the case in the software industry. Patenting in this industry has become a field of war as evident in the explosion of litigation cases, even for codes which are considered as general knowledge. While many studies have been performed for well established technologies like the above, policy recommendations to guide regulations for relatively new technologies such as LEDs are lacking. Despite very rapid change in technologies and standardisation efforts made by large companies, we know little about the extent to which patenting systems in general, and threats of litigations in particular, deter firms from innovating. By addressing the question of the extent to which litigation patents have the potential to deter innovation by smaller firms, we will be able to highlight the extent to which patent wars in this sector are based predominantly on strategic, political, or technological bases. This distinction in turn is important for designing and implementing policies which will shape the evolution of technologies in this field. Finally, since comparative life cycle assessments of various lighting technologies suggest that all the environmental impacts of the future generations of LEDs will be much lower than the ones of other lighting technologies, we assume that forthcoming LED innovation are ecoinnovations, namely that for the same service, in this case providing a certain amount of lumens per watt, they generate less ecological impacts that existing alternatives.

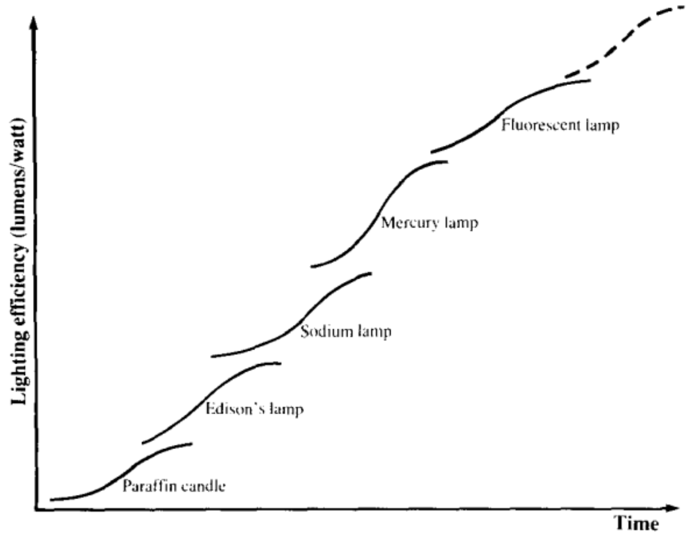
The paper is organised as follows. In the second section we introduce the LED sector, the literature on barriers to innovation, and the one on patent litigations. In the third and fourth sections, we present the method and data used in this study, before turning to the results and their discussion.

2. Empirical background

2.1. Lighting in a nutshell

Looking a few thousand years back one finds that fuel combustion has dominated the long history of lighting. For example, DiLaura (2008: 23) explains that “The first records of fire-making appear in the Neolithic period, about 10,000 years ago”, and 4,500 years ago in modern day Iraq oil lamps were used to burn oils made from olives and seeds. The first candles appeared 2,000 years ago in Rome but were too expensive for being used for ordinary lighting. It was only in 19th century that chemical advances using stearine and especially paraffin in the 1860s replaced animal and vegetable oils, which enabled improvements of more elaborated lamps like the one developed by Ami Argand in 1784 (Bowers (1980)). The next important technological change appeared at the same period with the development of (at first coal) gas lighting, which permitted the large illumination of cities in the 19th century. Gas mantle burners using rare earth elements further improved luminous efficiency and were only challenged by the introduction of electric arc and incandescent lighting. Before the fast diffusion of the latter technologies, discharge lamps based on mercury (1932) or sodium were also used. Early work on incandescent lamps dates from about 1840, and following works by Joseph Swan, Thomas Edison showed in 1879-1880 the importance of deep vacuum, and in October 1879 built and tested what he called a “filament” lamp (Bowers (1980: 27)). Today solid state lighting is becoming the dominant lighting technology (see the dotted line in the figure below).

Figure 1. Successive waves of lighting technologies



Source: Wissema (1982), quoted in Olleros (1986: 7).

As Hall et al. (2014) underline, "Although photo-emissive properties of semiconductor diodes have been known since the 1950s (...) it was not until 1997 when Japanese electronics company Nichia introduced a white 5 mm LED that produced a single 0.1 W white LED (WLED) sufficiently bright for reading in complete darkness". A few years later the 2014 Nobel prize winner Nakamura invented the blue LED light, after tormented years of innovation-intensive activities (see Qiu (2007)). The LED sector is an innovation-intensive field since it bridges several fields of knowledge such as electronics and photonics (Zheludev (2007))". In a previous research published in Cecere et al. (2014), we highlighted that "Solid state devices using organic materials", which correspond to the LED sector, was the most innovative technological domain of all green ICT sectors in terms of patent growth. A recent report indicates that 36% of the 2,032 patent families filed between 1996 and 2013 in phosphor LED material technologies were filed over the last 5 years.[1]

Because of fast market growth and changes in legal environment (e.g. the phasing out of incandescent lamps), the LED market is highly dynamic (McKinsey & Company (2012)). At the moment, the commercial/tertiary sector represents 43% of the lighting market (31% for the residential sector and 18% for the industrial sector (De Almeida et al. (2014)). Sales on the global lighting market will amount to more than 100 billion Euros in 2020 (80% for general lighting), and thus McKinsey & Company (2012) deems it the most promising technology in terms of commercial viability by 2020, ahead of electric vehicles. As a consequence, the LED share in general lighting will be 45% in 2016 and 70% in 2020 (ibid.), facilitated by standardisation efforts in the industry which could overcoming major technological hurdles such as efficient heat sinks or universal drivers designed for 50,000 hours. Residential is and will remain the main LED market segment followed by office and outdoor lighting. But Konnerth (2012) stresses the growing usage of LED products in commercial lighting has prospects to increase at an annual rate of 39% and sales of 4.5 billion dollars by 2015. With the rise of LED lighting solutions, economic value in the lighting sector will shift to

[1] Source: LED Phosphors and Down Converters Patent Investigation, Report Sample, http://www.i-micronews.com/reports/LED-Phosphors-Down-Converters-Patent-Investigation/14/392/.

fixtures and lighting systems, changing the balance of power among the actors of the lighting regime. Also, new business opportunities will be created such as in control systems for LED lighting, especially in offices. In 2010, the global market for lighting products was estimated to be approximately € 80 billion, of which a very small, but fast growing, fraction is related to LED systems (De Almeida et al. (2014)). Indeed, the LED lighting market is anticipated to grow 45% per year through 2019: from $4.8 billion in 2012 to $42 billion in 2019[2] (for Bloom (2012) LED sales are projected to grow from $340 million in 2007 to $7.3 billion by 2014). In 2015, the market penetration of LEDs will be 16.8 % (Davis (2012)), and could reach 52% of the commercial lighting market by 2021.[3] The diffusion of LEDs is facilitated by the fact that it is used in many different products such as backlighting of mobile electronic devices, LCDs for televisions and computers, Architectural and mood lighting, Traffic signals, Billboards, hoardings and advertising signs, Exit signs and emergency lighting, Vehicle lighting, Street lamps and outdoor lighting, Road lighting, etc. (Viikari et al. (2012)). According to the LED Magazine, the top-ten list of LED manufacturers for 2013 was[4] Nichia, Samsung, Osram Opto Semiconductors, LG Innotek, Seoul Semi, Cree, Philips Lumileds, TG, Sharp, and Everlight. In terms of geographical location, Asia keeps leading the market demand (47% of 81 billion Euros market in 2020), followed by Europe (22%) and North America (18%). Value is moving downstream (from backlighting to general lighting). Some countries like Korea has selected the LED industry as a new growth engine for the 21st century and is geared to become one of the world's top three LED manufacturers in 2012 (Jang (2010)).

2.2. The knowledge base of LEDs

This dynamic growth of the sector is also reflected in the fast growing and highly complex knowledge base that characterises it. This aspect of the knowledge base is particularly important for our purposes in this paper. The expansion of the knowledge base is on one hand the result of the entry of many firms to the industry in its growing phase, so as to exploit the rich technological opportunities. But at the same time, the complex and fragmented nature of the knowledge base can augment the uncertainties about the future evolution of technologies. In return, dominant players can adopt strategies to gain power in the industry, through building consortia, use patent litigations as a signalling mechanism about the power of their own technologies, and rapidly build a market base through alliances with firms who can help in expanding their own standards in the market.

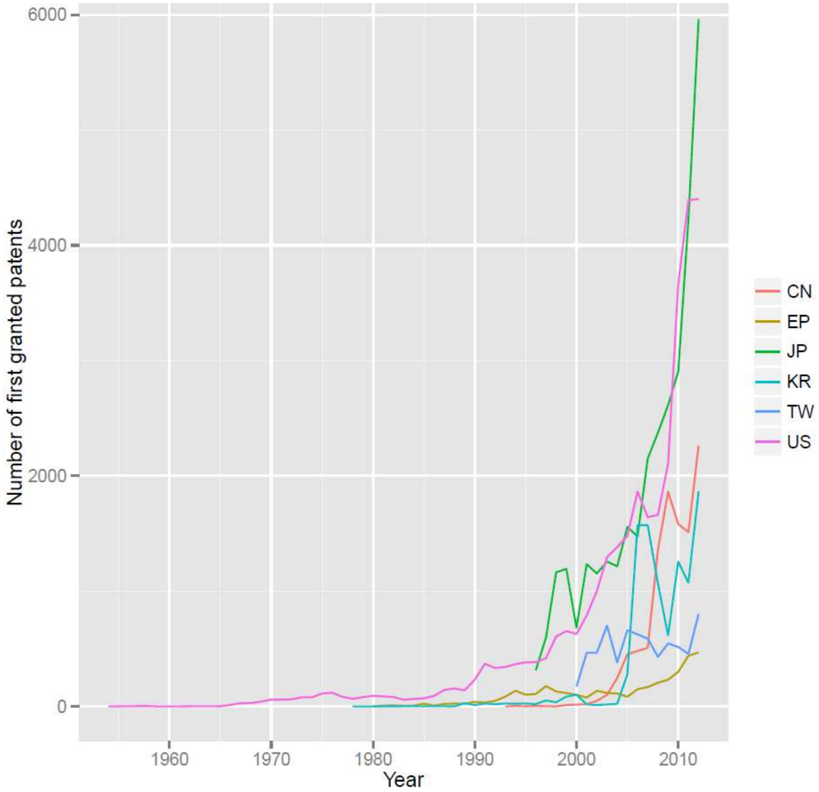
We will take the analysis of the knowledge base in two ways. The first is in terms of the growth of the knowledge base. The second one is with respect to the changing nature of recombinations which characterise innovation. Let us take each in return.

To reveal the growth of the knowledge base, Figure 2 shows the evolution of the number of patents in LED class through time and with respect to countries.

[2] Source: Report "LED Lighting: Market Shares, Strategies, and Forecasts, Worldwide, 2013 to 2019", http://www.reportsnreports.com/reports/269046-led-lighting-market-shares-strategies-and-forecasts-worldwide-2013-to-2019.html.
[3] Source: http://lighting.com/pike-research-leds/.
[4] Source: http://www.ledsmagazine.com/articles/2014/02/strategies-unlimited-projects-packaged-led-market-to-hit-25-9b-in-2018.html.

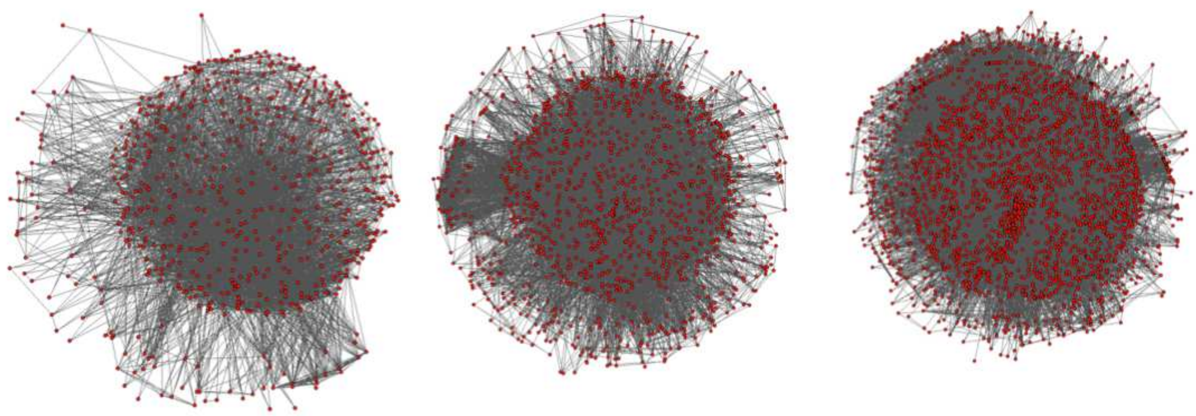
There is an important surge on LED related patent publication. Figure 2 shows the numbers of patent publications in H01L 33 IPC code in the most active patent offices. These patent offices are from China, Europe, Japan, Korea, Taiwan and US.

Figure 2. The growth of LED patents with respect to country



To reveal the complexity of the knowledge base, we also constructed a network of IPC classes included in the patent documents in three periods: 1980-1990; 1990-2000 and 2000-2010. In the networks, the nodes are IPC classes, and a link between two IPC classes exist if they appear in a patent document together.

Figure 3. IPC networks in LEDs



1980-1990

Core and periphery

1990-2000

Core expands with a few growing peripheral clusters

2000-2010

Core expands further, periphery narrows

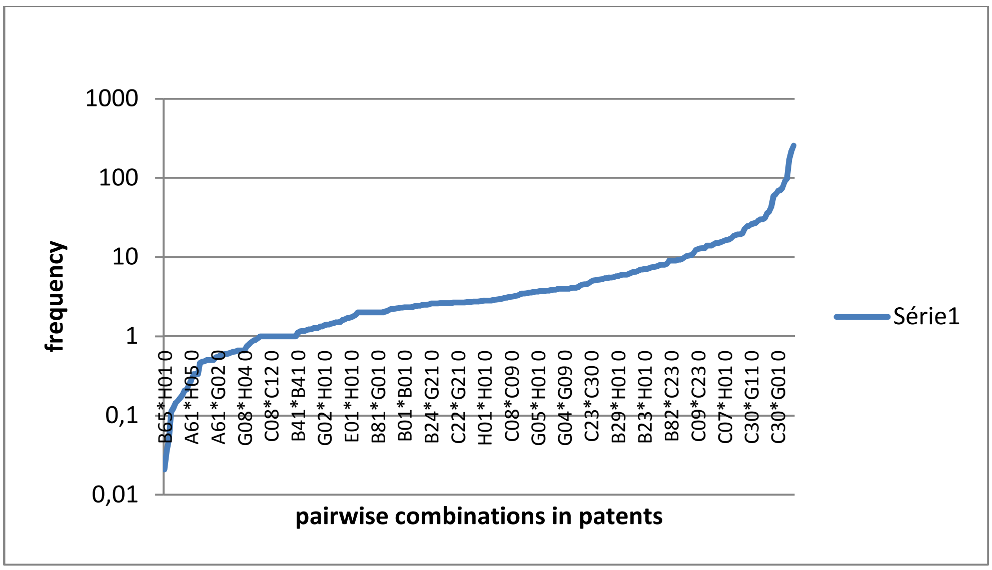
Table 1. Descriptive statistics, network of IPC classes

Period	Number of nodes	Links	Average degree centrality	Std dev	Skewness
1980-1990	621	5925	19.08	30.17	9.04
1990-2000	1254	18787	29.96	46.85	6.86
2000-2010	2662	55455	41.66	79.95	8.29

Table 1 shows some descriptive statistics concerning these knowledge clusters. It is possible to see that, there is a significant growth in the number of different subject matters incorporated into the LED domain, as evident from the growth in the number of nodes in the network throughout the period. Secondly, in each period we see that certain knowledge fields are "peripheral" in the network, that is to say that they are weakly connected within each other and to the core, where the core in return is strongly connected. These knowledge fields can be taken as "niche" subjects. In return, in each period these niche subjects are incorporated strongly to the core, as seen in the remaining periods where the core of the network grows significantly in the last two periods. In addition, we also see that after 2000, the peripheral has narrowed down, pointing to the possible saturation of knowledge dynamics, where the niches are now well established. As an illustration of these observations, consider Appendix 1, which shows the main IPC classes and their weight in patents in the three periods mentioned.

The changing nature of the knowledge base can also be seen in Figure 4, which shows the proportion of commonly co-occurring IPC classes between two periods: 2000-2010 compared to 1990_2000. It can be seen that, while some IPC combinations became 'obsolete" from 1990s to 2000s (as revealed in the leftmost part of the figure, with a proportion below 1), other IPC combinations gained weight compared to 1990s (cf. the right parts of the graph, where the proportion of IPC combinations between the two periods is greater than 1). In return, rapid change in the nature and size of the knowledge base is also an indication of the intensive competition in the field, where protections on property rights are increasingly and aggressively maintained by firms through patent litigations.

Figure 4. Changing nature of recombinations



2.3. Barriers to innovation

In order to account for the barriers to innovation, we distinguish between barriers related to the firm itself or to its context. We also summarise the findings of an investigation of barriers to ecoinnovation in the LED sector.

Concerning barriers that are internal to the firm, three main categories can be highlighted: technology, human resources, and finance.

For technology-related barriers, besides the capacity to access finance, the understanding of market needs, the capacity to recruit high-skilled staff and to establish effective interaction with other actors, D'Este et al. (2012) underline that routines can deter innovation, as well as Loch et al. (2013); Becker et al. (2005), and Pentland et al. (2005). For example, large firms can face resistance to adjust competencies and previously successful organisational practices. For Baldwin et al. (2002), difficulties to trigger internal changes can be due to the computer aided-design system put in place, and the age of staff that can explain a lack of knowledge in new technologies, as well as workers' resistance to novelty, which might be caused by a lack of scientific and technological information. Zammuto et al. (2007) also suggests that IT systems can block innovation, for example because they fail to deliver new information to staff members about new technologies and markets opportunities. Reinstaller et al. (2010) also stresses the lack of technological knowledge as an innovation barrier, which can occur when firms internationalise (lack of knowledge about expanding markets & technologies). Small firms that are not part of large groups seem more likely to face such a problem. Barriers to knowledge transfer also create obstacles to innovation (Szulanski (2003)), as well as the lack of collaboration to share knowledge in complex systems (Dougherty et al. (2011)). For Baldwin et al. (2002), the cost of innovations can hinder their development because of capital investment, of the acquisition of the technology and of related equipment, of software development, and of increased maintenance expenditures. Mohnen et al. (2005) also argue that innovation can be deterred because it is too hard to control its costs. Some barriers are specific to the LED sector and concern for example light glare or uncomfortable light spectrum that can deter the adoption of new lighting products (Clear (2013) Hickcox et al. (2013), Islam et al. (2013)).

Concerning human resources-related barriers, Mohnen et al. (2005) underlines the problem of personnel skills within enterprises, which can be due to the fact that their innovation potential is too small to attract specialised engineers, that their staff lacks information on technologies and markets, or that they tend to resist to changes. Reinstaller et al. (2010) stress that small, young, innovative and growth-oriented firms are more heavily affected by skill constraints. Other barriers of this kind include the role of human resource management and complementarity in green business strategies (Antonioli et al. (2013)), and the nature of the type of leadership in the company (Hirshleifer et al. (2012)).

Concerning financial barriers, Mohnen et al. (2005) claim that the lack of appropriate sources of finance, excessive perceived risk, high innovation costs (also mentioned by Vogel (2005)), the fact that the pay-off period of innovation is too long are obstacles to innovation, as well as uncertainty about returns on investment (Bergemann (2005)). The impact of financial constraints on innovation has also been stressed by Savignac (2008) and Tiwari et al. (2007) because they deter R&D investment, as well as by Madrid-Guijarro et al. (2009) who underline that the costs associated with innovation have a higher impact on small firms. For Canepa et al. (2005) financial constraints are significant for both small and high-tech firms. These constraints correspond to the fact that some firms cannot find financing sources, that the setting of financing is too slow, or that interest rates are too high. For Reinstaller et al. (2010), financial barriers are particularly important for SMEs producing very novel products, which is supported by Alessandrini et al. (2010) for whom, following Baldwin et al. (2002), the more innovative firms are, the more barriers they face.

Other barriers to innovation concern firms' strategy (Vogel (2005) argues that uneven corporate environmental commitments can deter ecoinnovation), poor environmental performances (Tong et al. (2012)), or greenwashing (Delmas et al. (2011)).

Concerning barriers that are external to the firm, four main categories can be highlighted: markets, users, policies, and industry.

For D'Este et al. (2012), market structure is a significant barrier faced by new firms. It relates to competition, firm size, and appropriability conditions. Indeed, new firms have a disadvantage in markets which are large and less competitive because their main competitive advantage derives from the capacity to coordinate complementary assets and new firms often do not possess that. As for Baldwin et al. (2002), they stress that labour market imperfections can cause difficulties to find higher skill levels (shortage of certain skills on the market, training difficulties in trying to overcome these or to change recruits, …).

Concerning user-related barriers, Vogel (2005) stresses that the lack of demand for greener products can deter ecoinnovation, whereas Kemp (2012) underline the importance of consumer awareness about ecological issues. Mohnen et al. (2005) also put forward the lack of customer responsiveness to new products and processes, as well as uncertainty in the timing of innovation.

Policy-related barriers include legislation, norms regulation, standards, R&D tax credit, capital cost allowances, or the fact that policies are not consistent enough or that environmental policies are not innovation-friendly (Mohnen et al. (2005), Baldwin et al. (2002), Foxon et al. (2008)). The way property rights are managed can also create obstacles to innovation, as in the case of hold up problems (Arundel (2001), Dolmans et al. (2011)).

Examples of industry-related barriers are the lack of opportunities to collaborate with other firms, and technology institutions or deficiencies in the availability of external technical services (Mohnen et al. (2005)). In the case of the LED sector, Chen et al. (2011) showed that the "co-opetition" behaviour between two LED manufacturers (Nichia and Osram) enabled them to solve patent litigations and to boost their innovation potential. In the biotechnology industry, Zidorn et al. (2012) suggest a positive innovation effect of alliances. For Leiponen (2008) and Assink (2006), the lack of industry standards can also block innovation, whereas Austin et al. (2012) put forward the lack of space for diversity and serendipity. For Tong et al. (2012), the position in the product chain can negatively impact innovation, as in the case of the LED sector where for example lamp assemblers do not control the manufacturing of LED drivers.

Finally, based on this literature review as well as on exchanges with LED experts, as part of an FP7 project we conducted a qualitative assessment of barriers to ecoinnovation in the LED sector.[5] These barriers are summarised in the next table.

Table 2. Major barriers to eco-innovation according to cycLED SMEs

Category	Barrier
Policies & norms/Policy instruments	Lack of certification mechanisms to check out the technical specifications of products put on the market
FINANCE	Lack of in-house sources of finance
FINANCE	The gross intrinsic value of the LED product is too low, which discourages innovation in recycling technologies
TECHNOLOGY	LED drivers are barriers to ecoinnovation
LED industry	Increasing & unfair competition from non-European firms
Policies & norms/Policy objectives	National policies do not provide adequate support to ecoinnovation and/or emerging LED technologies
FINANCE	Eco-innovation costs are too difficult to control
RESOURCES & CAPABILITIES	Information systems are sources of rigidity that discourage ecoinnovation
LED industry	Existence of litigations between firms
Markets & User practices/Financial markets	Lack of funding to support SMEs' ecoinnovation
Markets & User practices/Labour market	Lack of skilled people to repair used LED products
Markets & User practices/Technological niches	Lack of modularity between radical innovations
HUMAN RESOURCES	Lack of technical personnel to ecoinnovate
Markets & User practices/Labour market	Educational institutions do not provide enough people well trained to develop ecoinnovations

NB: Capital letters = INTERNAL BARRIERS. Bold font underlined: **score of 5**. Bold font italics: ***score of 4 with two level 2.*** Bold font: **score of 4**. Italics: *score of 3*. Normal font: score of 2.

2.4. Patent litigations and innovation

In this paper, our aim is to investigate the extent to which litigated patents in the LED industry are different in terms of their qualifying attributes from other (non litigated) patents. This issue is particularly important in the case of LEDs because of the following reasons. Firstly, most of the literature on patent litigations is concerned with the software industry. In the literature, it is frequently mentioned that in the case of software, patenting does not only increase the costs of imitation but it also creates barriers to the following research in a strong IPR regime (Dosi et al., 2006; Bessen and Hunt, 2007). Moreover, strategies like patent thicketing (Shapiro, 2001) in a strong IPR regime creates considerable amount of legal complexities in industries such as software. Patent lawyers and non-practicing entities (NPEs or patent trolls) became important figures in the software industry due to the increasing number of patent litigation cases. Moreover, it is reported that 94% of the patent lawsuits are related to software patents (Allison et al., 2009). Software industry and

[5] This part of the research has been presented in the 2014 International Schumpeter Conference, see Gossart (2014).

manufacturing industries are obviously different in terms of the extent to which patenting presents a barrier to innovation.

Notwithstanding these differences, in most manufacturing industries, and particularly in fast growing ones like LEDs, little research exists to investigate the relation between innovation performance of small and medium sized enterprises, and the cases of patent litigation. The fact that there is a tremendous increase in patent litigations can be a barrier to innovation by small firms (see Figure 5). Two mechanisms explain how. First, increased litigations point to strong IPR regimes, where firms are forced to cross-license the technologies. So, litigations are expected to increase cross-licensing. Whereas this can be a promoter of innovation in general among incumbent firms of similar capabilities, this can have a negative effect on the innovation potential of new entrants or small firms which are not robust enough to engage in cross-licensing. To the extent that litigated patents are more valuable than others, this poses even more problems since their uses over a wide range of products can further strengthen the market power of incumbents in favour of their own standards, and can weaken the innovative capabilities of small firms. The second mechanism by which patent litigations can act as barriers to innovation is through a preventive effect of penalty. The conventional wisdom is that firms demand patent protection in order to safeguard their intangible assets, which are easy to copy and distribute at minimal marginal cost. Without such protection, other producers could copy the innovation without incurring any of the 'sunk' development costs. Infringement and imitation work to dissipate the gains to firms and thereby reduce (ex ante) their incentives to innovate. A common view held by most firms is that, if there were no patent litigations, no one would pay licence fees. While in terms of protecting the rights of innovators, patent litigations are advantageous to provide incentives for innovation, the downside can be their potential to reduce variety in the system and promote a "rich get richer" cycle. Figure 6 shows the litigation network, where a link is defined between two firms if they are subject to a litigation lawsuit. It can be seen that the network is quite dense with many incumbent firms taking place.

Figure 5. Number of patents and litigations

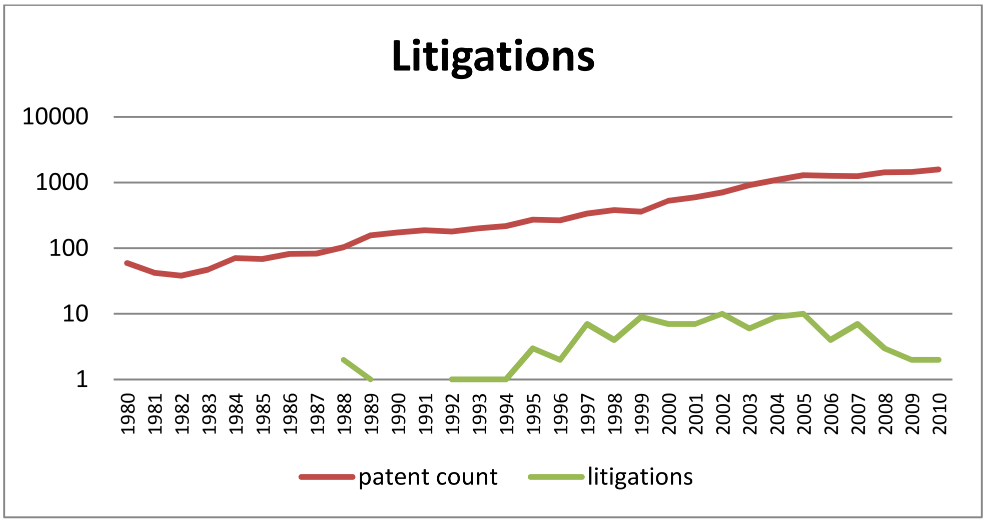
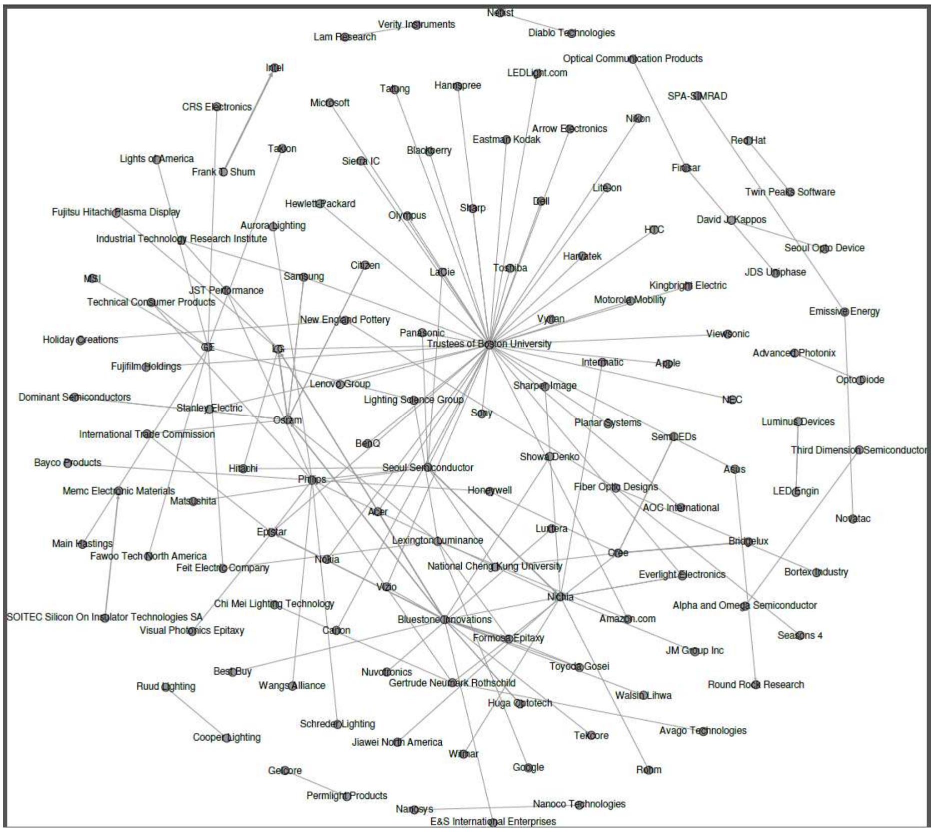


Figure 6. Litigation network



The literature on patent litigations and innovation has been growing rapidly during the last years. In these studies, one of the central questions has been which patents are likely to be subjected to be litigation? In general, this largely depends on the dynamics of the sector under investigation.

Most often, patents are seen as a way to encourage innovation (Hall (2007)). It is also argued that the resulting effects of the patent system are not the same for all technologies. In some cases such as the chemical, pharmaceutical and biotechnology industries, patents could promote innovation (Arora et al. (2001)). However, it is also argued that strong patent protection has a negative effect on innovative activities in "cumulative system technologies" such as software, radio and aircraft technologies (Nelson (1994), Mazzoleni et al. (1998)). The particularities of these technologies are that they are built on top of previous inventions and that a single product contains a large quantity of patents. Thus, a product based on cumulative system technologies contains numerous patented inventions. It is also suggested that strong IPR regime did not play an important role in the emergence of ICTs and it is not a tool for value generation. Dosi et al. (2006) claim that weak IPR regimes played an important role in the emergence and diffusion of transistor, semiconductor and mobile telephony technologies. Allison et al. (2009) report that 94% of patent lawsuits are related to software patents, notably because of the activities of non practising entities (NPEs). According to Bessen et al. (2011), "NPE lawsuits are associated with half a trillion dollars of lost wealth to defendants from 1990 through 2010".

Patents are one of several strategies to manage knowledge, and Arundel (2001) underlines that "a higher percentage of firms in all size classes rate secrecy as more valuable than patents." But when they do, why firms apply for patents? Allred et al. (2007) summarise the reasons for which firms

engage in patenting activities (to block rivals from patenting related inventions, as a source of bargaining power when cross-licensing, to measure internal performance, or to stimulate domestic innovation and attract foreign technology. Hall et al. (2001) add that stronger patent rights could facilitate entry by specialised firms and contribute to industry vertical disintegration. On the other hand, opponents argue that imitation helps catching up and that strong patent rights deter learning and innovation. Along these lines, Mazzoleni et al. (1998) argues that "there is reason for concern that the present movement towards stronger patent protection may hinder rather than stimulate technological and economic progress." Besides, patents have side effects such as the fact that "patent rights held by different parties can block each other and deter innovation" (Bessen (2000)).
For Veer et al. (2012), individual inventors tend to use patents to block knowledge diffusion. As for small firms, Leiponen et al. (2009) suggest that they seem to prefer secrecy or speed to market strategies. But patenting strategies also vary depending on the market conditions at stake in a given sector. For example, Wang et al. (2010) underline that "under high environmental dynamism, firms should increase the diversity in their knowledge composition in order to mitigate the risk of value erosion associated with firm-specific innovations." On the other hand, Blind et al. (2009) suggest that companies' patenting strategies are related to the characteristics of their patent portfolios. For example, in the LED sector when patenting rates slow down big players will tend to pursue more defensive patenting strategies in order to safeguard and make the most of their patent pools in terms of financial profit sources. For example, Useche (2014) finds significant and robust positive correlations between patent applications and IPO performance.

But the extent to which patents favour innovation also depends on the patenting system itself, whose side effects can deter innovation as in the cases of "submarine patents" (Allison et al. (2000)) or of "patent trolls". As Lemley et al. (2004) explain, the latter originate from "non-practicing entities", namely firms that license patents without producing goods, the term "troll" coming from the "practice of hiding under a bridge they did not build and demanding a toll from surprised passersby". They appropriate profits from innovation solely by enforcing patents against infringers, and tend to rely on low-quality patents (Fischer et al. (2012)). As a consequence, argue Belenzon et al. (2013), "USPTO patents have no effect on firm value in late periods". Pénin (2012) also argues that patent trolls tend to be R&D decreasing. For Reitzig et al. (2007), patent trolling exploits legal system flaws to increase financial profits, and if this especially true for the US, Blackman (2014) suggests that there is a risk of extension to Europe.

Hall et al. (2007) argues that small firms are increasingly subjected to such attacks. This generates huge costs for businesses, up to $29 billion in the US (Marks (2013)). Kingston (2001) adds that patents can also be used "as a bargaining currency to prevent "lock-out" from use of state-of-the-art components developed by competitors", leading to "patent portfolio races" or "patent predation" (Chien (2009)). For example, Grimpe et al. (2014) underlines that "infringement increases the likelihood of cross-licensing". For Lanjouw et al. (1997), "more valuable patents and those with domestic owners are considerably more likely to be involved in litigation".

Such side effects challenged the view that the most-litigated patents tend to be the most-valuable patents. On the contrary, Allison et al. (2003) argue that "the intuitive relationship between value and litigation is indeed the right one". For Bessen et al. (2005), legal changes are the most likely explanation to the patent litigation explosion. Indeed, because of the hazards involved with patent infringement, those who contemplate a punishable offense might refrain from infringing, not to

mention the moral influence of punishment (Andenas (1966)): it is *wrong* to copy one's discoveries! Thus: "Infringement and imitation work to dissipate the gains to firms and thereby reduce (ex ante) their incentives to innovate" (Allred et al. (2007)).
For Lanjouw et al. (2001), there is a relationship between patents' characteristics and litigation likeliness. If some patents are more likely to be subjected to litigations, they should have specific characteristics compared to non litigated patents. Allison et al. (2003) find important differences in a range of dimensions, for example some sectors are more prone to litigations than others (e.g. computers more than electronics), patents issued to individuals or small firms tend to be more often litigated than those from big companies, and "patents that cite more prior art are more likely to be litigated, and those that are litigated tend to be cited more elsewhere"[6].

According to the United States Government Accountability Office (2013), three key factors can contribute to patent infringement lawsuits: unclear and overly broad patents, the potential for disproportionately large damage awards, and the increasing recognition that patents are a valuable asset. This US government report indicate that patent monetization entities (PMEs) represent about one lawsuit in five, a number which is on the rise. Litigated patents have been studied by a variety of papers. For example, Allison et al. (2009) underlines that a great share of the most-litigated patents belong to software and telecommunications sectors, and that they made "extraordinary use of patent continuations". For Bessen (2006), patent disputes occur because of imitation, "inventing around", hiding or unaware infringement. Bessen et al. (2008) add that the private costs of patent litigation contribute to scare off small firms if they feel that they run the risk of being sued or if they felt like suing, since "the expected joint loss to the litigating parties is large". And it goes much beyond lawyers' costs; since it causes time loss to deal with the prosecution, strains relationships between firms, increases credit costs because of possible bankruptcy, and can even lead to injunctions to shut down production and sales.

3. Method

In this paper, we are concerned with the nature of litigated patents. For this purpose, two points are important to consider, from a methodological and a theoretical point of view. Firstly, to identify the nature of a set of patents, we need to have a reference set of patents to exmine the extent to which these patents are different from the rest. Because the nature of technology is highly context specific, for this purpose we compare the litigated patents with the rest of the patents in the LED sector. Secondly, we need to define a set of variables to explore the nature of technology in these domains.

Underlying our approach in this paper is the idea that patent litigations have the potential to deter innovations. Several reasons lie behind the mechanisms through which this happens. The first mechanism is related with the general preventive effects of punishment (Andeanar, 1966). Firms, especially small ones which have innovative potential but lack financial and other resources, can be deterred from innovating when exposed through media, and professional circles about the cases of litigation. This is critical especially in technological fields which encompass many components,

[6] For a recent review of the literature on patent opposition, see Caviggioli et al. (2013), according to whom existing studies can be grouped into three main strands of literature.

subsystems, or knowledge areas, and in which patenting is significant. In these cases, recombination opportunities are high, due to variety, yet, when there is strong protection of each knowledge field/ component, building upon others innovations becomes costly in environments of strong patent protection. The prevention effect of litigations will deter firms, or at least constrain firms in, exploring different technologies in a cumulative manner. The second mechanism is direct. Small firms may be deterred from innovation because litigations increase the costs of innovations.

In short, our approach is based on the idea that if litigated patents have certain technological characteristics which makes them different from the rest of the patents, litigation cases would further deter other and more peripheral firms to innovate in related fields. Because our aim is to analyse the technological nature of patents subject to litigation, to highlight their characteristics we need to take into account a reference set so as to identify the extent to which litigated patents and the reference set are significantly different in terms of their number of variables.

In this research, comparisons of patent characteristics are used to distinguish the differences between the group of litigated patents from the group of those which are not litigated within the patents being classified within the H01L 33 IPC code. In order to understand whether these two groups of patents are different from each other, we used discriminant function analysis. This technique allows us to compare two or more groups which are characterised with multiple parameters. Discriminant function analysis will help us distinguish the characteristics of the litigated patents from the ones of those which are not litigated. This method is used to distinguish groups having similar sample numbers. In our case, the number of patents which are not litigated and those which are used in patent litigation cases are very different. In order to overcome this problem, we have randomly selected a set of non-litigated patents, which has the same number of non-litigated patents. We have conducted 10 experiments and calculated the average from these 10 experiments. In discriminant function analysis we have only used H01L 33 class patents which are litigated. The discriminant analysis is carried out only for the 1990-2000 and 2000-2010 (see Schoenmakers and Duysters (2010) where they compare radical and non-radical inventions using a similar methodology).

4. Data and Measures

LED technology-related patents are classified within the H01L 33 IPC code. For this research patent data were collected from EPO PATSTAT 2014 April edition and litigation data were obtained from MAXVAL (http://litigation.maxval-ip.com). Table 3 gives the number of patents analysed in this study. Due to the distribution in patents over time, analyses are carried out for three periods of 10 years starting from 1980. Litigations are searched based on patent class of H01L 33 and 172 cases are obtained. In each patent litigation case, the number of patents changes and patents which are classified other than the H01L 33 are also obtained. Thus, the number of unique patents which are subject to litigation is 187, among them 98 are classified in H01L 33 IPC code.

Table 3. Patent descriptive statistics

Application filing year	1951-1980	1980-1990	1990-2000	2000-2010	2010-2014	TOTAL
Patent count (H01 L33)	842	751	2571	10507	3435	18106
Litigated patent count	0	15	53	97	3	187
Litigated patent count (H01 L33)	0	3	28	58	2	98

Because our ultimate aim is to assess the extent to which patent litigation cases can be a barrier to innovation, especially for small firms and new entrants, we need to find the main dimensions upon which we will base the comparison of litigated and non litigated patents. In other words, we ask the following question: **which characteristics of litigated patents** (had they been different from others) **would most deter other firms from innovating?** In this study, most of the variables that we consider are related to the extent to which these patents are valuable in terms of being applicable to a wide range of areas, or as being the basis of novel recombinations which can have potential uses in many areas. For this purpose, we use the following dimensions, and we also look at the extent to which patents are scientific.

Dependent and independent variables

The dependent variable in this study is whether the patent is subject to a litigation or not, the variable LITIGATION is a dummy variable; it is 0 if the patent is not litigated and 1 if the patent is used in one of the litigation cases that we have collected from MAXVAL.

According to the literature various patent properties are found to be correlated with the economic value of patent. The first independent variable that we construct is the number of citations to other patents (PAT_CIT). The lack of citations to other patents means that this patent contains a pioneering invention (Ahuja et al. (2001)).

As a second measure, we look at the number of citation that a patent received, since the number of forward citation are found to be correlated with the economic value of patent (Griliches (1990), Trajtenberg (1990), Van Zeebroeck (2011)). The number of forward citations (FWD_CIT) is an indicator for the technological importance of a patent (Dahlin et al. (2005)).

As a third dimension, we are interested in the scientific content of patents. Patents containing citations to scientific papers (SCI_CIT) are also find to be valuable and they are more cited by other patents (Gittelman et al. (2003); Fleming and Sorenson, 2004).

As a fourth variable, we look at the number of claims (CLAIMS) that a patent contains, which is also used as a proxy for the quality of patents (Lanjouw et al. (2004)). The procedure to publish a patent is quite different from country to country, thus some of the patent properties should be evaluated with care. One of the properties which is important in USPTO system is the number of claims that a patent contains. This information is an important parameter which shows the extent of the protection granted to a patent.

The scope of a patent is represented with the IPC code(s) that a patent contains. IPC code is also used to understand the knowledge sources. The higher the number of IPC code that a patent contains the wider the knowledge source of that patent. Moreover, the scope of a patent portfolio of a firm is also measured with the variety of the IPC code that this portfolio includes. This indicator is showed to be correlated with the market value of firms (Lerner, 1994). All variables used in this study are given Table 4.

Table 4. Variables used in this study

Variable	Definition
LITIGATION	dummy variable 0 if no litigation 1 if patent is used in litigation
PAT_CIT	number of citation to patents
FWD_CIT	forward citation, number of patents citing the patent
SCI_CIT	number of citation to scientific work
CLAIMS	number of claims
IPC	number of IPC that the patent is classified

Table 5. Correlation table for H01L 33 patents

	LITIGATION	PAT_CIT	FWD_CIT	SCI_CIT	CLAIMS	IPC
LITIGATION	1.000	0.046	0.087	0.058	0.040	0.037
PAT_CIT	0.046	1.000	0.049	0.809	0.257	0.174
FWD_CIT	0.087	0.049	1.000	0.074	0.143	0.120
SCI_CIT	0.058	0.809	0.074	1.000	0.183	0.146
CLAIMS	0.040	0.257	0.143	0.183	1.000	0.099
IPC	0.037	0.174	0.120	0.146	0.099	1.000

5. Results and Discussion

In order to understand which variables can be distinguished between the two groups of patents (litigated ones vs. not litigated ones), we start by investigating the correlations between variables. Table 5 shows that the only strong correlation is between PAT_CIT and SCI_CIT. This result shows that as the patents having higher scientific knowledge are also contains higher number of patent citations.

Tables 6 and 7 show the group statistics for all variables in the main patent group of LEDs and those of litigated patents respectively. Looking to the group statistics it is clear that patents which are litigated receive much more patent citations on both directions and also have higher citations to scientific work. Moreover, they also cover more knowledge as it can be found from the CLAIMS and IPC values. However, because the sample sizes are different, the discriminant function analysis was performed by taking into account randomly selected patents from the main group, equal to the size of the litigated patents group. The results of the discriminant function analysis are presented in Table 8.

The results of the discriminant function analysis made for the periods 1990-2000 and 2000-2010 show that the accuracy of this methodology increased for the second period where the technology matures but also the number of litigated patents also increases. In perfect classification we should obtain 1 as the predictive accuracy and 0 if the classification could not discriminate any patent as being litigated or not. The predictive accuracy for the 1990-2000 period is 0.67 and for the period 2000-2010 it is 0.78 and the overall performance is close to 0.67 as shown in Table 9.

Table 6. Group statistics for the H01L 33 patents (n = 18106)

	Mean	Std.dev.
LITIGATION	0.01	0.07
PAT_CIT	23.23	32.22
FWD_CIT	2.79	5.66
SCI_CIT	4.63	12.64
CLAIMS	15.51	12.18
IPC	5.52	3.89

Table 7. Group statistics for the H01L 33 litigated patents (n = 98)

	Mean	Std.dev.
LITIGATION	1.0	0.0
PAT_CIT	43.46	52.00
FWD_CIT	9.49	11.07
SCI_CIT	14.52	25.47
CLAIMS	22.08	14.29
IPC	7.47	6.22

The coefficient of linear discriminants in the next table indicates that the number of forward citation is the parameter which helps discriminate litigated patents from those which are not.

Table 8. Coefficient of linear discriminants

	LD1 (1980-2010)	LD1 (1990-2000)	LD1 (2000-2010)
PAT_CIT	0.005493129	0.006347935	0.002548592
FWD_CIT	0.092404235	0.080323561	0.167974538
SCI_CIT	0.011774441	0.040219856	0.005432954
CLAIMS	0.012741730	-0.010253949	0.023555925
IPC	-0.021956102	-0.110886475	-0.017744943

Table 9. Classification Processing Summary

Years	Result
1980-2010	0.70
1990-2000	0.67
2000-2010	0.78

6. Concluding Remarks

In this paper, we investigated innovation dynamics in the LED industry through a patent analysis. In particular, our interest focused on the extent to which the patents subject to litigation in the case of LEDs are significantly different, along a few dimensions, from other patents that are not subject to litigations. This question is important, especially for the case of LEDs, for which there has been an intensive innovative activity during the last decade. In the growth phase of industries, there is rapid innovation and incumbents strive to set the dominant standards in the industry, especially where complementary systems are important in technological evolution, like LEDs. To yield an insight about the technological and knowledge base of the industry, we carried out some preliminary patent analyses. Indeed, there has been a tremendous growth in the number of patents, and also in the range of different fields encompassed in LED innovations. Moreover, not only the *growth*, but the *change* in the nature of technological developments is striking, where growth happens through increasingly incorporating previously peripheral niche components into the main area, and a rapid creation of new recombinations which did not exist previously.

The significance of such an evolution of the knowledge base, for our purposes, stems from the fact that, in such industries, striking a balance between protection of innovations on the one hand, and supporting variety on the other hand can be a daunting task for policy makers, especially in the face of powerful incumbent firms striving to set their own standards through rapid innovation and building consortia with other firms. Consequently, small firms that lack financial resources can be driven out of the innovation arena. Because of the "no visibility" of such firms, it is difficult to explore the extent to which this is really the case. Nonetheless, our point of departure in this paper was to investigate the nature of patents subject to litigations. The link between innovation barriers and patent litigations is important in two ways. Firstly, patent litigations can have a preventive effect on firms, in which they refrain from engaging in innovative activities because of being exposed to increasing threats of litigations. Even if cross licensing can be an option, many innovative firms may not have the resources and capabilities to be involved in cross licensing agreements. Secondly, to the extent that the patents which are subject to litigations are more "valuable" in terms of their potential to be applicable in a wide range of technologies, aggressive protection of proprietary technologies can create a vicious cycle in which we observe the rich get richer phenomenon, driving out potential variety in the market.

Our results reveal indeed that litigated patents are significantly different in terms of their scientific basis, and in terms of their potential use in later innovations. It is important to note that this paper *does not* draw conclusions about the extent to which patenting systems are barriers to innovation, simply because our empirical analysis does not permit us to draw conclusions about that issue. Rather, by drawing upon innovation literature, we underline that striking a balance between protection and variety promotion is critical, not only in software industries (for which there is an enormous literature) but also for technologies which are in their growth phase, and which have the potential to be applied in a wide range of areas, as in the case in LEDs.

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APPENDIX 1

THE EVOLUTION OF IPC CODES INVOLVED IN LED PATENTS IN THE THREE PERIODS

Explanation	**IPC**	**1980-1990**	**1990-2000**	**2000-2010**	**Growth**
BAKING; EQUIPMENT FOR MAKING OR PROCESSING DOUGHS; DOUGHS FOR BAKING	A21			1	-
SPORTS; GAMES; AMUSEMENTS	A63			1	-
SEPARATION OF SOLID MATERIALS USING LIQUIDS OR USING PNEUMATIC TABLES OR JIGS; MAGNETIC OR ELECTROSTATIC SEPARATION OF SOLID MATERIALS FROM SOLID MATERIALS OR FLUIDS; SEPARATION BY HIGH-VOLTAGE ELECTRIC FIELDS	B03			1	-
BRAIDING; LACE-MAKING; KNITTING; TRIMMINGS; NON-WOVEN FABRICS	D04			1	-
PAPER-MAKING; PRODUCTION OF CELLULOSE	D21			1	-
WEAPONS	F41			1	-
BRUSHWARE	A46			2	-
MAKING PAPER ARTICLES; WORKING PAPER	B31			2	-
BUILDING	E04			2	-
FURNACES; KILNS; OVENS; RETORTS **[4**	F27			2	-
COMBUSTION APPARATUS; COMBUSTION PROCESSES	F23			3	-
DRYING	F26			3	-
NATURAL OR MAN-MADE THREADS OR FIBRES; SPINNING	D01			4	-
YARNS; MECHANICAL FINISHING OF YARNS OR ROPES; WARPING OR BEAMING	D02			4	-
MUSICAL INSTRUMENTS; ACOUSTICS	G10			4	-
WRITING OR DRAWING IMPLEMENTS; BUREAU ACCESSORIES	B43			5	-
TREATMENT OF WATER, WASTE WATER, SEWAGE, OR SLUDGE	C02			5	-
COMBINATORIAL TECHNOLOGY	C40			5	-
HEATING; RANGES; VENTILATING	F24			5	-
CLEANING	B08			6	-
PETROLEUM, GAS OR COKE INDUSTRIES; TECHNICAL GASES CONTAINING CARBON MONOXIDE; FUELS; LUBRICANTS; PEAT	C10			6	-
HAND OR TRAVELLING ARTICLES	A45			8	-
AGRICULTURE; FORESTRY; ANIMAL HUSBANDRY; HUNTING; TRAPPING; FISHING	A01	3		10	-
DECORATIVE ARTS	B44			15	-
FURNITURE; DOMESTIC ARTICLES OR APPLIANCES; COFFEE MILLS; SPICE MILLS; SUCTION CLEANERS IN GENERAL	A47			16	-
LAYERED PRODUCTS	B32	2		209	-

SHIPS OR OTHER WATERBORNE VESSELS; RELATED EQUIPMENT	B63		3	1	-0.67
RAILWAYS	B61		6	2	-0.67
CONSTRUCTION OF ROADS, RAILWAYS, OR BRIDGES	E01		6	2	-0.67
ONVEYING; PACKING; STORING; HANDLING THIN OR FILAMENTARY MATERIAL	B65		5	2	-0.60
HABERDASHERY; JEWELLERY	A44		2	1	-0.50
LAND VEHICLES FOR TRAVELLING OTHERWISE THAN ON RAILS	B62	1	1	1	0.00
MECHANICAL METAL-WORKING WITHOUT ESSENTIALLY REMOVING MATERIAL; PUNCHING METAL	B21		2	2	0.00
PRINTING; LINING MACHINES; TYPEWRITERS; STAMPS [4]	B41	82	224	235	0.05
REFRIGERATION OR COOLING; COMBINED HEATING AND REFRIGERATION SYSTEMS; HEAT PUMP SYSTEMS; MANUFACTURE OR STORAGE OF ICE; LIQUEFACTION OR SOLIDIFICATION OF GASES	F25	2	3	4	0.33
BIOCHEMISTRY; BEER; SPIRITS; WINE; VINEGAR; MICROBIOLOGY; ENZYMOLOGY; MUTATION OR GENETIC ENGINEERING	C12	2	5	7	0.40
ENGINEERING ELEMENTS OR UNITS; GENERAL MEASURES FOR PRODUCING AND MAINTAINING EFFECTIVE FUNCTIONING OF MACHINES OR INSTALLATIONS; THERMAL INSULATION IN GENERAL	F16		5	7	0.40
SIGNALLING	G08		19	27	0.42
INFORMATION STORAGE	G11	19	57	87	0.53
ELECTRIC COMMUNICATION TECHNIQUE	H04	76	368	609	0.65
COMPUTING; CALCULATING; COUNTING	G06	12	41	69	0.68
MEDICAL OR VETERINARY SCIENCE; HYGIENE	A61	11	68	116	0.71
BASIC ELECTRONIC CIRCUITRY	H03	20	32	57	0.78
CHECKING-DEVICES	G07		1	2	1.00
PHYSICAL OR CHEMICAL PROCESSES OR APPARATUS IN GENERAL	B01	1	46	98	1.13
CASTING; POWDER METALLURGY	B22		16	41	1.56
OPTICS	G02	200	802	2103	1.62
NUCLEAR PHYSICS; NUCLEAR ENGINEERING	G21		7	21	2.00
METALLURGY; FERROUS OR NON-FERROUS ALLOYS; TREATMENT OF ALLOYS OR NON-FERROUS METALS	C22	1	6	19	2.17
EDUCATING; CRYPTOGRAPHY; DISPLAY; ADVERTISING; SEALS	G09	46	252	830	2.29
MICRO-STRUCTURAL TECHNOLOGY [7]	B81		7	25	2.57
WORKING CEMENT, CLAY, OR STONE	B28	1	3	11	2.67
ELECTROLYTIC OR ELECTROPHORETIC PROCESSES; APPARATUS THEREFOR [	C25	5	7	26	2.71
BASIC ELECTRIC ELEMENTS	H01	2974	11640	43284	2.72
ELECTRIC TECHNIQUES NOT OTHERWISE PROVIDED FOR	H05	101	418	1602	2.83
MEASURING; TESTING	G01	50	101	393	2.89

COATING METALLIC MATERIAL; COATING MATERIAL WITH METALLIC MATERIAL; CHEMICAL SURFACE TREATMENT; DIFFUSION TREATMENT OF METALLIC MATERIAL; COATING BY VACUUM EVAPORATION, BY SPUTTERING, BY ION IMPLANTATION OR BY CHEMICAL VAPOUR DEPOSITION, IN GENERAL; INHIBITING CORROSION OF METALLIC MATERIAL OR INCRUSTATION IN GENERAL [2]	C23	17	61	240	2.93
HEAT EXCHANGE IN GENERAL	F28		2	8	3.00
CEMENTS; CONCRETE; ARTIFICIAL STONE; CERAMICS; REFRACTORIES **[4]**	C04		6	24	3.00
VEHICLES IN GENERAL	B60	5	51	211	3.14
GRINDING; POLISHING	B24		5	22	3.40
CRYSTAL GROWTH [3]	C30	61	214	964	3.50
INORGANIC CHEMISTRY	C01		42	202	3.81
WORKING OF PLASTICS; WORKING OF SUBSTANCES IN A PLASTIC STATE IN GENERAL	B29	3	29	140	3.83
AIRCRAFT; AVIATION; COSMONAUTICS	B64		1	5	4.00
ORGANIC MACROMOLECULAR COMPOUNDS; THEIR PREPARATION OR CHEMICAL WORKING-UP; COMPOSITIONS BASED THEREON	C08	6	96	489	4.09
HOROLOGY	G04		1	6	5.00
PHOTOGRAPHY; CINEMATOGRAPHY; ANALOGOUS TECHNIQUES USING WAVES OTHER THAN OPTICAL WAVES; ELECTROGRAPHY; HOLOGRAPHY **[4]**	G03	26	44	278	5.32
CONTROLLING; REGULATING	G05		12	78	5.50
MACHINE TOOLS; METAL-WORKING NOT OTHERWISE PROVIDED FOR	B23	1	11	86	6.82
DYES; PAINTS; POLISHES; NATURAL RESINS; ADHESIVES; COMPOSITIONS NOT OTHERWISE PROVIDED FOR; APPLICATIONS OF MATERIALS NOT OTHERWISE PROVIDED FOR	C09	7	204	1762	7.64
LIGHTING	F21	50	292	2863	8.80
NANO-TECHNOLOGY	B82		9	110	11.22
ORGANIC CHEMISTRY [2]	C07	1	20	300	14.00
GENERATION, CONVERSION, OR DISTRIBUTION OF ELECTRIC POWER	H02	1	5	90	17.00
GLASS; MINERAL OR SLAG WOOL	C03	7	2	45	21.50
SPRAYING OR ATOMISING IN GENERAL	B05	1	1	99	98.00

APPENDIX 2

Top 10 issuing litigation

Trustees of Boston University	43
Bluestone Innovations	24
Osram	8
GE	8
Nichia	7
Seoul Semiconductor	7
Philips	7
Lexington Luminance	6
Gertrude N. Rotschild	5
Frank T. Shum	4

Top 10 defendant firms in H01L33 related patent litigation cases.

LG	12
Osram	11
Cree	8
Nichia	7
Epistar	66
Formosa Epitaxy	5
Philips	4
Intel	4
Seoul Semiconductor	4
Samsung	4