ARE LITIGATED PATENTS MORE VALUABLE? THE CASE OF LEDs

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Are litigated patents more valuable? The Case of Light Emitting Diodes

Abstract

In this study, we examine the nature of LED-related litigated and non-litigated patents, and explore the main drivers of patent lawsuits. The results indicate that litigated LED patents are of significantly higher scientific quality compared to non-litigated ones. From our analysis we obtained three results. First, patent litigations in the LED sector are the result of innovation-related factors. Second, even though the quality of defended patents is high, two leading plaintiffs are non-practicing entities. Third, litigations are in general between incumbent firms. We discuss these results with respect to the studies related to patent litigations and their effects on innovation in general and eco-innovation in particular.

Keywords: patents; litigations; LED; lighting; eco-innovation; barriers.

1. Introduction

During the recent decades the lighting sector has been going through a radical transition ranging from incandescent technologies to energy efficient LED (light emitting diode) systems. LEDs are today used in a wide array of markets such as lighting, but also in flat panel displays with organic LEDs (Kajikawa & Takeda, 2009). 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 (De Almeida et al., 2014). As in any growing technological field, LEDs also seem to have witnessed their share of standard wars, as evident in many consortia built 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.

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 sector? 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 future technologies. These technologies are particularly important, because many following inventions 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 litigated patents 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 the above

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, particularly areas in a strong IPR regime (Dosi et al., 2006; Bessen and Hunt, 2007). For example, while in the case of technologies like pharmaceuticals and biotechnology 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. But we do know that IPR protection is very important for small firms since they "place a higher importance on using patents as signals to investors" (Veer & Jell, 2012). 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 that will shape the evolution of technologies in this field.

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. Background

2.1. The LED market and its knowledge base

LED technologies have a wide variety of applications that span across multiple sectors such as lighting, backlighting or signalling. A key motivation to adopt LED light sources is their energy efficiency and their durability compared to alternatives. Therefore, the diffusion of LED products and services has the potential to generate substantial savings in electricity costs for adopters, and to contribute to fight climate change especially in countries with a carbon-intensive energy mix. Besides, LED lighting sources offer much more flexibility in terms of lighting design, and enable a wider use of smart lighting systems (street lighting, smart buildings, etc.). With the phasing out of incandescent light bulbs happening in many countries across the world, these factors explain why the LED sector is highly dynamic (Schulte-Römer, 2015).

The LED sector represents more than 40% of the lighting market (De Almeida et al., 2014). Sales on the global lighting market are expected to amount to more than 100 billion Euros in 2020, making LEDs one of the most promising technologies in terms of commercial viability, ahead of electric vehicles. By 2020, the LED share in general lighting is expected to reach 70%, thanks to standardisation efforts in the sector to overcome major technological hurdles, such as efficient heat sinks or universal long lasting LED drivers designed for 50,000 hours (ibid.). Nowadays, LEDs are used in many different products such as backlighting of mobile electronic devices, LCDs for televisions and computers, architectural and mood lighting, traffic signals, billboards, emergency lighting, vehicle lighting, street lamps and outdoor lighting, road lighting, etc. (Viikari et al., 2012).

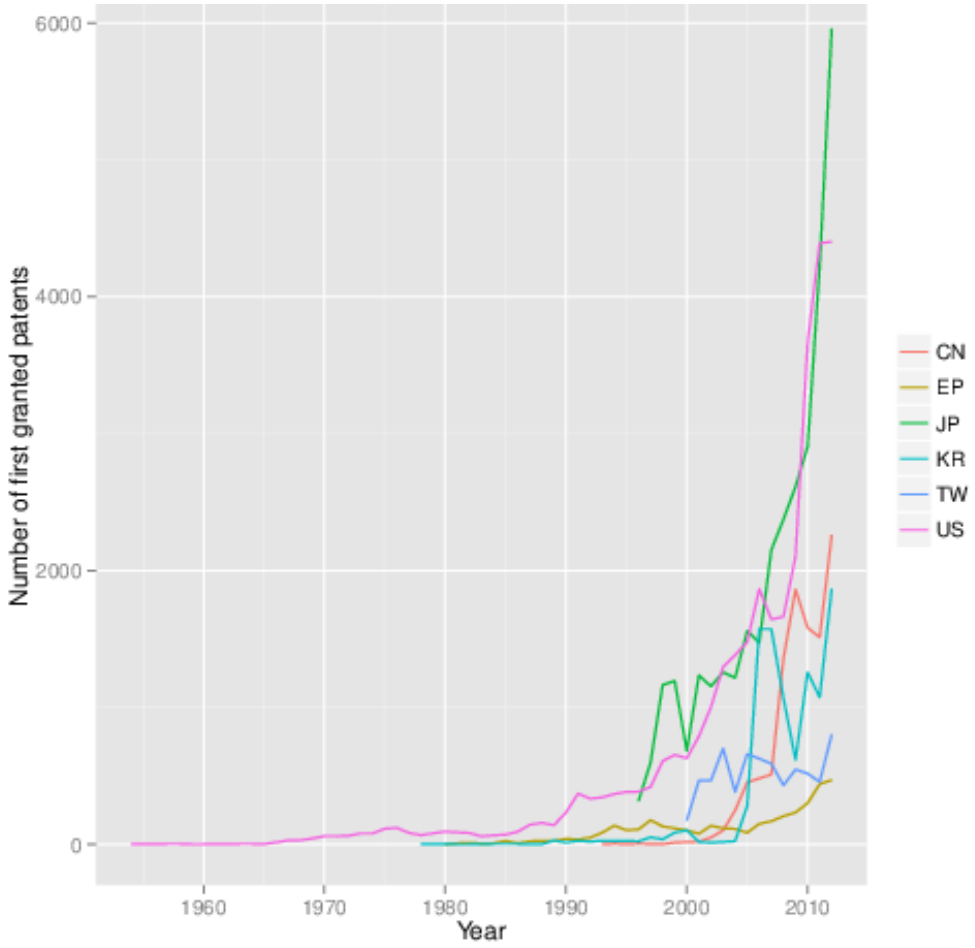
Within the LED market, the main segment is residential, followed by office and outdoor lighting. The fast growth in the sales of LED products and services is expected to trigger a shift of economic value downstream from backlighting to general lighting (fixtures and lighting systems). This will change the balance of power among the firms in the sector, and incumbent lighting firms will be under

pressure to adapt their strategies and business models to these changes. New business opportunities include LED lighting control systems, especially in offices, as well as offering light as a service. By 2020, Asian countries will concentrate the bulk of world market demand (47% of 81 billion Euros market in), followed by Europe (22%) and North America (18%). Some countries like Korea have selected the LED sector as a new growth engine for the 21st century, and managed to join the world's top LED manufacturers (Jang, 2010).

What are the key characteristics of the knowledge base supporting the growth of the LED sector? According to Dosi et al. (2006: 1126), a knowledge base is "the set of information inputs, knowledge, and capabilities that inventors draw on when looking for innovative solutions". Therefore, the knowledge base of an industry refers to the collective knowledge that is stored, shared, disseminated, and assimilated by organisations and inventors in an industry. One way to account for this knowledge base is to examine the patents issued to firms in a given field. By analysing patents, Cecere et al. (2014) found that the LED sector was the most innovative technological domain among all green ICT sectors in terms of patent growth. In addition, the LED knowledge base bridges a variety of technological fields such as electronics and photonics (Zheludev, 2007), supporting the rapid diffusion of LED technologies in multiple sectors. Figure 1 shows the exponential growth in LED patents, especially between 1990 and 2010 for the IPC[1] class H01L33.

[1] International Patent Classification.

Figure 1. Yearly published LED patents in the six leading patent offices for the IPC class H01L33 between 1953 & 2012



The dynamic growth of the sector is reflected in the fast-growing and highly complex knowledge base that characterises it. The expansion of this knowledge base results from the entry of many firms in the sector in its growing phase, and from the exploitation of rich technological opportunities. At the same time, the rapidly expanding and complex nature of the knowledge base augments uncertainties about the future evolution of the technology, especially with respect to the various markets that the technology can be used in (Rosenberg, 1996). In the case of LEDs, the past 30 years have witnessed an impressive growth in the diversity of markets outlets, and this trend seems to be continuing.

Together with the rapid growth of markets and innovations, the impact of intellectual property rights (IPR) regimes on LED innovation dynamics has become increasingly important. Indeed, if strong IPR regimes can stimulate innovation by protecting inventors, they can also deter innovation because imitation becomes more difficult, which slows down innovation diffusion. As previous literature suggests, this trade off depends on multiple factors that are discussed in the next section.

2.2. Strong IPRs and innovation

The impacts of a strong IPR regime on innovation rely on a multiplicity of factors. According to the literature, patents encourage innovation (Hall, 2007), especially in science-based industries like the chemical, pharmaceutical and biotechnology (Arora et al., 2001). At the same time, strong IPR regimes can have a negative effect on innovation in “cumulative system technologies”, such as the software, radio and aircraft (Nelson, 1994; Mazzoleni and Nelson, 1998). These technologies build upon previous inventions, and a single product contains a large quantity of patents.

In general, imitation helps catching up and strong patent rights may deter learning and innovation through imitation. According to the literature, in the case of software, patenting does not only increase the costs of imitation but also creates barriers to subsequent research in a strong IPR regime (Dosi et al., 2006; Bessen and Hunt, 2007). Along these lines, Mazzoleni and Nelson (1998) express concern that stronger patent protection may hinder technological and economic progress.

Stronger patent protection can take the form of high licence fees and even of lawsuits, whether there are risks of IPR infringement (patent litigations) or not (strategic manoeuvring). A common view held by most firms and industry experts

is that, if there were no patent litigations, no one would pay licence fees.[2] Therefore, patent litigations indicate the strength of sanctions in the IPR regime and the extent to which it is enforced in an industry. The costs associated with patent litigations have a preventive effect of potential infringers. At the same time, threats of lawsuits for IPR infringement can be used as pre-emptive strikes to scare-off innovative competitors. Some of the latter may then prefer to licence their inventions or to keep it secret instead of risking a costly and uncertain legal battle. Because of the hazards involved with patent infringement, those facing a punishable offense might refrain from infringing property rights, not to mention the moral influence of punishment (Andenas 1966). Thus, as Allred and Park (2007) put it, "Infringement and imitation work to dissipate the gains to firms and thereby reduce (*ex ante*) their incentives to innovate". As a consequence, if patent litigations protect the property rights of inventors and incentivize innovation, their downside is a possible reduction of technological variety and the promotion of a "the rich get richer" cycle.

A significant increase in patent litigations could discourage innovation, especially by small firms. It could push firms to cross-license technologies, whose prices would increase because of lawsuits. Therefore, innovation by new entrants or small firms not robust enough to engage in expensive cross-licensing would be discouraged. For Bessen (2006) patent disputes occur because of imitation, "inventing around", hiding, or unaware infringement. Bessen and Meurer (2008) add that the private costs of patent litigations contribute to scare-off small firms if they feel that they run the risk of being sued or if they feel like suing others, since "the expected joint loss to the litigating parties is large". This loss 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. Patent litigations can even lead to injunctions to shut down production and sales. In addition, since LEDs have a wide array of applications in high-tech industries, these negative impacts on innovation would

[2] Source: expert interviews carried out for the cycLED project. See https://gossart.wp.imt.fr/cycled.

spill over beyond the LED sector. As a result, aggressive litigation strategies could slow down the diffusion of an energy-efficient technology in many sectors and countries.

To protect their market, incumbent firms could use these strategies to deter innovation. As explained in the next section, such strategies imply litigated patents are not necessarily of higher quality than others. Therefore, if LED litigated patents tend to have a low value, it is likely that those litigations are used to deter innovation by new entrants, and the IPR regime could well deter innovation instead of supporting it.

2.3. Are litigated patents of higher quality than others?

The scientific or technological quality of litigated patents provides insights about innovation dynamics in an industry and about the strategies of incumbent firms. According to Lanjouw and Schankerman (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. As Allison et al. (2003) underline: "the intuitive relationship between value and litigation is indeed the right one", and the authors find important differences across several dimensions. For example, some sectors are more subjected to litigations than others (e.g. computers more than electronics). Also, patents issued to individuals and small firms tend to be more often litigated than those issued to large firms. Besides, patents that cite more prior art are more likely to be litigated, and litigated patents tend to be cited more by other patents (Allison et al., 2009). Most litigated patents belong to the software and telecommunications sectors, which have made an "extraordinary use of patent continuations" (ibid.). According to the United States Government Accountability Office (2013), three key factors contribute to patent infringement lawsuits: unclear and overly broad patents, a potential for disproportionately large damage awards, and the increasing recognition that patents are a valuable asset. What does it mean in terms of industry dynamics that litigated patents have a higher value?

The high scientific or technological quality of litigated patents, together with an increasing number of litigations in a field,[3] indicates an increased competition among existing firms, a rapidly growing technology and uncertainty in future markets, and an intensive level of activity to prevent future entrants.

But are litigated patents always of high value? In fact the value of litigated patents may not always be higher than that of non-litigated patents. Incumbents use patenting and litigations as strategic tools to send signals to existing competitors and to protect themselves against potential ones, even when the concerned inventions do not have any scientific or technological significance.

To protect their inventions as well as to maximise the financial value of their patent pool, incumbent firms can resort to many IPR-related and other strategies. As Allred and Park (2007) explain, patenting aims to prevent rivals from protecting related inventions, by increasing their bargaining power in the event of cross-licensing. It also helps them measure their internal performance, stimulates domestic innovation, and attracts foreign technology investments.

For example, in the lighting sector dominant players pursue a wide range of strategies to secure their market shares. They are developing consortia through their market legitimacy and established networks, and rapidly build a market base through alliances with firms that can help them diffuse their own standards. Another strategy consists in using patent litigations to signal proprietary technologies ('strategic signaling'). While litigated patents may, at the time of the lawsuit, be of little significance, litigations can be used by incumbent firms as a mechanism to prevent the emergence of other innovations and to weaken competitors (Andenas, 1966). Firms lacking financial and human resources, especially small ones with a strong innovative potential, can be deterred from innovating when litigation cases are exposed in the media and in professional circles. This is a critical issue, especially for technologies with a high growth potential such as the LED ones. Together with the strategic signaling activities of

[3] For Bessen and Meurer (2005), legal changes are the most likely explanation to the patent litigation explosion.

large firms, the fact that the future uses of a growing technology are uncertain may deter firms with high innovative potential to make a full use of it, thereby reducing technological variety in the industry.

The preventive effect of litigations will deter firms from exploring different technologies in a cumulative manner. One of the implications of using patent lawsuits to block rivals' entry in future markets can be to slow down the innovation activities of highly capable small and dynamic firms, whereas these firms could play a key role in the generation of innovations and eco-innovations (Cecere et al., 2014). Using patents for strategic signaling may be a sign of industry evolution. 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 tend to pursue more defensive patenting strategies such as litigations, in order to safeguard and maximise profit from their patent pools, even though litigated patents are of little scientific and technological significance. These strategies can also serve the purpose of asset management, since significant and robust positive correlations have been found between patent applications and Initial Public Offering (IPO) performance of software firms (Useche, 2014).

These "patent trolls" license patents without manufacturing any product (Lemley and Moore, 2004). They capture profits from innovation solely by enforcing patents against infringers, and to do so they tend to rely on low-quality patents (Fischer and Henkel, 2012). Patent trolls can have a negative effect on firm value in the future (Belenzon and Patacconi, 2013), might decrease R&D spending (Pénin, 2012), and exploit legal system flaws to increase profits (Reitzig et al., 2007). In the past decade the LED sector has witnessed an increased number of Non-Practiced Patents (NPP) litigations (Lane, 2010). These activities deter innovation, it is thus interesting to analyse whether they are gaining momentum in a high-tech sector such as the LED one. These parasite activities could undermine innovation in a sector that has a significant role to play in saving energy and tackling climate change.

3. Data and Methodology

3.1. Data

This paper investigates whether litigated patents in the LED sector are different in terms of their qualifying attributes from other (non-litigated) patents. Most of the literature on patent litigations is concerned with the software industry, as it is reported that 94% of patent lawsuits concern software patents (Allison et al., 2009). However, there are no studies that investigate litigation cases in the LED sector.

LED-related patents are predominantly classified within the H01L33/00 - 33/64 IPC classes, shortly with the H01L33 class. Patent data was collected from EPO PATSTAT (2014 April edition), and litigation data was obtained from the MAXVAL database.[4] A total of 18,106 USPTO patents were analysed (see Table 1). Due to the distribution of patents over time, analyses were carried out for three periods of 10 years starting from 1980. Table 1 shows the number of patents by country (applications and first grants) for the period 1951 to 2013.

Table 1. World filled and granted patents per country of application

Country	*Number of granted patents*	*Number of patent applications*
US	18,106	27,715
Japan	13,932	49,931
Korea	6007	13,985
Taiwan	4026	9207
EP	2133	7949
China	6448	16,380

Table 2 shows the top 20 LED patenting firms according to USPTO dataset.

[4] Maxval is a firm specialized in patent analyis. In this study we have used Maxval Litigation Database.See http://litigation.maxval-ip.com.

Table 2. Top 20 USPTO applicant firms in H01L33 code

Firm	# of USPTO patents
TOSHIBA CORPORATION	577
SHARP CORPORATION	524
PANASONIC CORPORATION	482
LG INNOTEK COMPANY	481
SAMSUNG ELECTRONICS COMPANY	463
SONY CORPORATION	448
SEMICONDUCTOR ENERGY LABORATORY COMPANY	445
OSRAM OPTO SEMICONDUCTORS	375
TOYODA GOSEI COMPANY	367
CREE	347
NICHIA CORPORATION	329
ROHM COMPANY	272
SUMITOMO ELECTRIC INDUSTRIES	251
SAMSUNG ELECTRO MECHANICS COMPANY	232
PHILIPS ELECTRONICS	221
SAMSUNG DISPLAY	214
LG DISPLAY	205
SHOWA DENKO	204
STANLEY ELECTRIC COMPANY	200
EPISTAR CORPORATION	174

In the LED sector, the number of litigations has increased steadily in the past 20 years. A total of 172 litigation cases were collected based on patent class H01L 33. Because a litigation case may involve more than one patent, the 172 cases include a total of 187 patents. Thus, the number of unique patents subjected to litigation amounts to 187, among which 98 use the H01L33 IPC code. The difference between these numbers indicate that the LED technological field is closely related with other fields, which may be due to the multi-sectoral application potential of LEDs, or to their heterogeneous knowledge base. Tables 3 and 4 show the top 10 plaintiff and defensive inventors in our litigation

cases. The most valuable patent (US5686738) is subjected to 43 patent litigation cases. It is owned by Boston University, which is also the plaintiff that started the highest number of litigation cases in the LED sector (Table 3). Then comes Bluestone Innovation with 24 cases, General Electric with 8 cases, and Osram with 8 cases. The second top plaintiff (Bluestone Innovation) is a non-practicing entity (NPE), in other words a patent troll. As for firms which have been sued, we find LG with 12 cases, followed by Osram, Cree, and Nichia (Table 4).

Table 3. Top 10 plaintiff firms involved in litigation cases mentioning patents using the H01L33 code

Name of organisation	Number of litigations
Trustees of Boston University	43
Bluestone Innovations	24
Osram	8
GE	8
Nichia	7
Seoul Semiconductor	7
Philips	7
Lexington Luminance	6
Gertrude Neumark Rotschild	5
Frank Schum	4

Table 4. Top 10 defendant firms involved in litigation cases mentioning patents using the H01L33 code

Name of organisation	Number of litigations
LG	12
Osram	11
Cree	8
Nichia	7
Epistar	6
Formosa Epitaxy	6
Philips	5
Intel	4
Seoul Semiconductor	4
Samsung	4

3.2. Methodology

To analyse the nature of litigated patents in the LED sector, two issues are important from a methodological and a theoretical point of view. Firstly, to identify the characteristics of a set of patents, one needs to have a reference set to examine the extent to which patent set differs from others. For this purpose, we compare litigated patents with non-litigated ones in the LED sector. Secondly, we define a set of variables serving as indicators of the qualitative attributes of LED patents.

In this research, we compare litigated and non-litigated patents, with respect to a range of patent characteristics. In order to understand whether these two groups of patents differ, a discriminant function analysis is used. This method allows us to compare two or more groups characterized by multiple parameters. In general, this method is used to compare groups of similar sample size. However, in this case the number of litigated patents is significantly smaller than the rest. In order to overcome this problem, a set of non-litigated patents was randomly selected, comprising the same number of non-litigated patents. We conducted 10 experiments and calculated the average from these 10 experiments (Table 5).

Table 5. Descriptive statistics of our patent sample

Application filing year	1951-1980	1980-1990	1990-2000	2000-2010	2010-2014	Total
Patent count	842	751	2571	10507	3435	18106
Litigated patent count	0	15	53	97	3	187
Litigated patent count (H01L33)	0	3	28	58	2	98

In this study, most of the variables are the indicators of scientific bases, the extent to which future inventions build upon the patent, and the applicability of the patent in various fields. For this purpose, we use the variables described below.

The **dependent variable** (LITIGATION) shows whether the patent is subjected to litigation or not. It is a dummy variable set to 0 if the patent is not litigated and to 1 if the patent has been used in at least one litigation case.

According to the literature, various patent characteristics can be used as an indicator of the economic value of a patent (**independent variables**). The first independent variable is the number of citations that a patent has received. This metric has been found to be correlated with the economic value of a patent (Griliches, 1990; Trajtenberg, 1990; Van Zeebroeck, 2011). Here we use the number of forward citations (FWD_CIT) as an indicator of the technological importance of a patent (Jaffe and Trajtenberg, 2005; Dahlin and Behrens, 2005).

For the second independent variable (SCI_CIT), we are interested in the scientific basis of patents. Patents containing citations to scientific papers have also been found to reflect patent value. Those patents are also cited more often by other patents in comparison with patents containing fewer citations to scientific papers (Gittelman and Kogut, 2003; Fleming and Sorenson, 2004).

The third independent variable accounts for the number of claims that a patent contains (CLAIMS), and can be used as a proxy for the quality of patents (Lanjouw and Schankerman, 2004). The procedure followed to publish a patent varies from country to country, and thus some patent properties should be evaluated with care. One of the properties which is important in the USPTO system is the number of claims that a patent contains. It is an important parameter showing the extent of the protection granted to a patent (Lanjouw et al., 2004).

The fourth independent variable is the scope of the patents, which is represented by the IPC codes that a patent contains (IPC). This code is used to identify the sources of knowledge upon which draws a patent. The higher the number of IPC codes mentioned in a patent, the wider its knowledge base. The scope of a firm's patent portfolio can also be measured with the variety of IPC codes contained in its portfolio. This indicator is correlated with the market value of firms (Lerner, 1994).

These variables are shown in Table 6, while correlations between our variables are provided in Table 7.

Table 6. Variables used in this study

Variable	Definition
LITIGATION	Dummy variable 0 if no litigation 1 if patent is used in a litigation case
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 a patent is classified

Table 7. Correlation table for H01L 33 patents

		1	2	3	4	5
LITIGATION	1	1				
FWD_CIT	2	0.087	1			
SCI_CIT	3	0.058	0.074	1		
CLAIMS	4	0.04	0.143	0.183	1	
IPC	5	0.037	0.12	0.146	0.099	1

4. Results

Tables 8 and 9 respectively show the group statistics for all variables in the main patent group of LEDs and those of litigated patents. Looking at these statistics it is clear that patents which are litigated receive much more patent citations, and also make more citations to scientific work. Moreover, they also cover a wider array of knowledge sources, as evidenced by the CLAIMS and IPC values.

Table 8. Group statistics for the H01L33 patents (n = 18106)

	n	mean	sd	se	min	max
LITIGATION	18106	1.01	0.07	0.00	0	1
FWD_CIT	18106	2.79	5.66	0.04	0	353
SCI_CIT	18106	4.63	12.64	0.09	0	110
CLAIMS	18106	15.51	12.18	0.09	0	188
IPC1	18106	5.52	3.89	0.03	1	49

Table 9. Group statistics for the H01L33 litigated patents (n = 98)

	n	mean	sd	se	min	max
LITIGATION	98	1.00	0.00	0.00	1	1
FWD_CIT	98	9.49	11.07	1.12	0	69
SCI_CIT	98	14.52	25.47	2.57	0	99
CLAIMS	98	22.08	14.29	1.44	2	70
IPC	98	7.47	6.22	0.63	1	27

The results of the logit analysis are shown in Table 10. The analysis that are carried out for the periods 1951-2013, 1951-2000 and 2000-2013 show that there is an important surge in the number of patents during the 2000s. During this period, not only does the technology mature, the number of litigated patents also increases.

The dependent variable LITIGATION is 1 if there is litigation related to the patent and 0 if there is not. The increase in the number of claims (CLAIMS), the number of references given to scientific work (SCI_CIT), and the number of forward citations (FWD_CIT) makes more likely for a patent to be litigated as shown in Table 10. On the other hand, an increase of the number of IPC that a patent is

classified does not have any effect on the likelihood of being litigated for the analysis made for the two time periods but a significant and positive relationship is present for the 1951-2013 period.

0shows the odds ratio of the logit models. If one of the patent characteristics increases by one unit and keeping all other parameters constant the odds that the patent is used on litigation is very low requiring a much higher number of increases to be subject to litigation. Moreover, the probability of a patent used in litigation is very low when all predictor values are kept to their means. The predicted probabilities are 0.4%, 0.5% and 0.3% for the 1951-2013, 1951-2000 and 2000-2013 periods respectively. These results show that there are important patent characteristics which create differences between litigated and non-litigated patents. We conclude that patents subject to litigation have a higher quality compared to the non-litigated ones.

Table 10. Logit results

	Dependent variable:	LITIGATION	
	(1951-2013)	(1951-2000)	(2000-2013)
CLAIMS	0.015***	-0.004	0.022***
	(0.005)	(0.013)	(0.006)
SCI_CIT	0.019***	0.041***	0.017***
	(0.004)	(0.011)	(0.005)
IPC	0.042**	0.037	0.035
	(0.017)	(0.032)	(0.024)
FWD_CIT	0.039***	0.053***	0.017***
	(0.010)	(0.013)	(0.006)
Constant	-6.063***	-5.687***	-6.229***
	(0.177)	(0.326)	(0.231)
Observations	18,106	4,164	13,417
Log Likelihood	-574.164	-166.926	-367.082
Akaike Inf. Crit.	1,158.327	343.853	744.163

Note: *p<0.1; **p<0.05; ***p<0.01

Table 11. Odds ratio

	Dependent variable:	LITIGATION	
	(1951-2013)	(1951-2000)	(2000-2013)
CLAIMS	1.0151**	0.9959	1.0218***
	(0.005)	(0.013)	(0.006)
SCI_CIT	1.0192***	1.0420***	1.0171***
	(0.004)	(0.011)	(0.005)
IPC	1.0426*	1.0379	1.0355
	(0.017)	(0.034)	(0.025)
FWD_CIT	1.0397***	1.0544***	1.0166***
	(0.010)	(0.013)	(0.006)

Note: *p<0.1; **p<0.05; ***p<0.01

5. Discussion

This paper analyzes whether LED patents subjected to litigation are significantly different, along a few dimensions, from other patents that are not subjected to litigations. This question is important for any industry, but especially is for one that produces eco-innovations in the form of rapidly growing energy-efficient technologies. In the growth phase of industries, there is a fast pace of innovation, and incumbents strive to set the dominant standards in the industry. This is especially true when complementary systems are important to drive technological evolution, which is the case in the LED sector. To yield an insight about the technological and knowledge base of this sector, we carried out exploratory patent analyses and found that there has been a tremendous growth in the number of LED-related patents as well as in the range of LED-related knowledge fields. The significance of such a sector stems from the fact that 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 a lack of 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 subjected to litigations.

The link between innovation and patent litigations is important in three ways. First, 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 engage in such agreements. Second, to the extent that the patents subjected 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. Third, the presence of non-practicing entities using low quality patents to sue innovating firms is an important threat to the diversity through the development of the sector with small, innovative firms which in many cases have fewer resources to be used for litigation.

Our results reveal indeed that litigated patents are significantly different in terms of their scientific basis, the number of claims and in terms of their potential use in subsequent innovations. The quality of patents subject to litigation is higher compared to the non-litigated ones. This shows that the litigation is indeed in the realm of innovation protected with high quality patents and not in an environment with various legal risks in which low quality patents are used as in the software industry. Moreover, the outcome of this study shows that the quality of the defended patents are high but on the other hand, two leading plaintiffs are non-practicing entities among which the leader is a university. There are examples of cooperation between incumbent LED companies (Chen and Chen, 2011). However, our data show that the litigation cases are in general between large, incumbent firms which have already created large patent portfolios.

One limitation of this research is the use of a database on patent litigation which does not take into account any out of court settlements. Patent infringements may be finalized with patent licensing agreements which may not be communicated. 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 the 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, have a critical role for energy saving, and which have the potential to be applied in a wide range of areas, as in the case in LEDs.

6. Conclusion

In this study we examined the quality of litigated and non-litigated patents related to the LED sector. We found that litigated patents had a higher quality compared to non-litigated ones. This result shows that patent litigations in the LED sector results from innovation-related factors rather than from firms' predatory behaviour. However, the characteristics of leading plaintiff firms are interesting since we could identify non-practicing entities among them, the leading one being a university. Our last finding highlights that fact that patent litigations in the LED sector are mainly between incumbent firms.

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Are litigated patents more valuable? The Case of Light Emitting Diodes

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Abstract

Recently the LED sector has been growing very rapidly, with an expanding knowledge base and an increasing array of markets in which LEDs are used. Consequently, the number of LED-related patents has increased exponentially, as well as the amount of patent litigations. One of the factors that can hamper innovation in such high growth fields is when incumbent firms use their patent pools to deter innovation by competitors, especially by smaller firms. If so, patents would undermine innovation instead of supporting it, and thus weaken LEDs' huge potential of energy savings. To shed light on the extent to which LED patents might be used to deter innovation in the sector, we examine the nature of litigated patents, compared with non-litigated patents, and explore the main drivers of patent lawsuits. The results indicate that litigated LED patents are of significantly higher scientific quality than non-litigated ones. From our analysis we obtained three results. First, patent litigations in the LED sector are the result of innovation-related factors. Second, even though the quality of defended patents is high, two leading plaintiffs are non-practicising entities. Third, litigations are in general between incumbents firms. We discuss these results with respect to the studies related to patent litigations and their effects on innovation.

Keywords: patents; litigations; LED; lighting; eco-innovation; barriers.