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W o r k i n g P a p e r

Exploring the correlation of patent ownership and firm success

– Cases from the LCD flat panel display industry

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I. Abstract

The rapid progress of electronic technology in recent decades has led to an increased technical complexity and wide functionality of many products. As a result man-machine interfaces, such as displays became more and more important, wherefore investments and technical progress in these technologies have been enormous since the early 1980s. Nowadays, the demand for small to large size, light weight (flat panel), high resolution, bright, contrast and real colour displays is very strong.

This paper emphasizes on patenting and success in the flat panel display (FPD) industry, which had experienced an extraordinary growth in the last decades. The paper focuses on the liquid crystal display technology (LCD) and in particular on the thin film transistor (TFT LCD) sub-technology, since the study indicates that from various FPD technologies, LCD and its sub-technology TFT is the most improved, commercially important and widely used technology for small to large display applications. The aim of the study is to explore the relationship between annual patent applications of eight leading manufacturers and the success in the market of these companies, with the success measured in terms of sales revenues.

The results of the study indicate that companies who aggressively patent are the most successful companies in terms of sales revenues and vice versa. A correlation analysis proves that the relation is strongest for a time lag between annual patent applications and subsequent sales revenues of one to two years, thus the optoelectronics could be considered to be a fast cycle-time industry. These findings are in clear contrast to evidence from prior studies, that prove the importance of patents only in particular industries, and especially in long-cycle time industries such as pharmaceuticals.

1. Introduction

The rapid progress of electronic technology in recent decades has led to an increased technical complexity and wide functionality of many products. As a result man-machine interfaces, such as displays became more and more important, wherefore investments and technical progress in these technologies have been enormous since the early 1980s. Nowadays, the demand for small to large size, light weight (flat panel), high resolution, bright, contrast and real colour displays is very strong. Developing these highly complex technology based products and technologies demands enormous investments in research and development (R&D).

As a matter of fact companies need incentives to carry out these risky investments throughout long term projects. As a commonly accepted mechanism companies are rewarded by being granted a temporary monopoly to be able to recover these investments. A system of particular importance for issues relating to R&D investments is the patent system. Being granted a patent for a technical invention, companies are given the exclusive right to make use of this technology, although just in the country in which the patent is granted. Although besides the patent system other systems for other so called intellectual property rights exist, this paper emphasizes particularly on annual patent applications. The aim of the study is to explore the relationship between the annual patent applications in the LCD and in particular the TFT-LCD technology and corresponding sales revenues of the patentees. The study tries to verify if a connection between those patent applications and the success level of the patentees exist. In this study, the success level of the patentees is measured in terms of sales revenues.

This paper is structured into six chapters. After this first chapter has given a short introduction to the research carried out, the second chapter discusses relevant theoretical concepts

regarding the economic impact of patents, presents findings from previous studies on the relation between patents and firm's performance, and facts regarding the importance of patents in different industries. The third chapter presents the research approach, the methodology applied including the scope and limitations of the study. The fourth chapter illustrates the development of the flat panel display industry in recent years and provides input regarding major players in this industry. The fifth chapter presents the research findings and the sixth chapter concludes this research and highlights issues for discussions and possible future research.

2. Patents as source of economic growth and prosperity

One expression of the technical success of R&D activities is a patent application. Thereby patents are regarded as a qualitative importance of R&D output and thus in general reflects the technological progress that lead to economic growth.[1] As a general idea of the patent system, inventors have to disclose detailed technical information of their inventions in exchange for being granted exclusive rights over their exploitation, thus the underlying idea of the patent system is to encourage market competition. The patent system stimulates economic development as both inventors and competitors race to create and to improve inventions to gain financial benefits or rewards, at least in certain industries.[2]

According to Pavitt (1988), empirical studies on patenting can be conducted on the level of countries, industries, technologies or firms[3]. On firm level, which is of relevance in this study, certain data included in the patent document can be used in aggregated form for business

[1] Ref. Griliches (1990).
[2] Ref. Idris (2003), P.6.
[3] Ref. Ernst (2001), P.143-144; Pavitt (1988).

intelligence purposes supporting managers in technical and economic decision-making. Patent information may be helpful for the analysis of technological trends to avoid over investments in particular technological fields that are fully patented or rather of decreasing importance. From a managerial point of view on firm level, the main function of a patent should be to help the company recover sufficient returns from its investment when commercializing a new technology. The quid pro quo for issuance of a patent is full disclosure of the invention[4].

For this reason, publicly and online accessible patent information can therefore be perceived to be increasingly useful for many user groups and purposes (both technological and economical). Depending on the purpose of the analysis, using different pieces of patent information combined with the information from other sources can provide valuable information[5] as support for business decisions.[6] E.g. Macdonald and Lefang (2003) list different purposes that patent data can serve that go beyond legal tasks: to prepare own patent applications, check on infringements, keep track of competitors, acquire information for opportunity, keep abreast of technical developments, avoid duplicating R&D, acquire information to solve problems, uncover new products, stimulate creativity. In fact, many studies have been carried out using patent information in recent years that serve different purposes, e.g. Ernst (2001), Trajtenberg (1999), Hall and Ham (1999), Grindley and Teece (1997), Kim (1997), Granstrand et al. (1997), Ehrnberg (1996), Mogee and Kolar (1994), Brockhoff (1992), Mogee (1991), Griliches (1990), Narin et al. (1987), Pavitt (1985, 1979).[7] Pursuing this notion and its consequence, patents become an increasingly valuable source for companies carrying out competitive intelligence.

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[4] Ref. Idris (2003), P.7.
[5] Ref. Granstrand (1999), P.289-317; Kuei et al (2006), P.248-253.
[6] Ref. Dreßler (2006), P.49.
[7] Ref. Granstrand (1999), P.290.

Consequently, the patent system stimulates economic development by promoting business activities. Businesses, from multinationals to small and medium-sized enterprises (SMEs) can benefit from patents itself and from the disclosed patent data by competitors. Besides that patent data has been commonly used more by large firms than by SMEs[8], one could argue that with free and easy access over the internet patent data increasingly becomes a valuable source of information for a wider number of companies, especially SMEs.

2.1. Patents and firm success

By holding patents companies should benefit from a monopolistic situation by owning a "legal title granting its holder the exclusive right to make use of an invention for a limited area and time by stopping others from making, using or selling it without authorisation"[9]. Theoretically, companies should be able to earn a higher price on products and recoup their investments in R&D, therefore feel an incentive to continuously invest in new ideas and as a consequence facilitate progress in society. Assuming that this general idea of the patent system works, companies that patent more than other should be able to appropriate more returns on their R&D investments, i.e. show higher sales revenues.

Analysing this phenomena, several studies have been carried out through the last decades. Table 2.1 gives a brief overview of some groundbreaking studies. Ernst (1995) found that firms with many patents of high quality are significantly more successful in terms of sales than companies without patents. Other studies, i.e. Narin (1987), Comanor and Scherer (1969), Scherer (1965) proved a positive relationship between patents and sales growth in different industries. Further studies, i.e. Austin (1993, 1995) investigated this relationship

[8] Ref. Macdonald and Lefang (2003).
[9] Ref. EPO (2005a), P.2; Teece (2003), P.137; Auger (1992), P.4-5.

quantitatively in biotechnology firms. Austin found that companies gained an average of 2.4 million USD a year in annual profits per patent. Primarily, those studies were conducted for firms within one country and within a largely homogeneous sector.

Authors	Sample	Variables	Method	Findings
Scherer (1965)	365 firms from the fortune 500 list (USA)	– Patents granted (1959) – Profits, sales growth (1955-1960)	– Cross-section analyses – Time lag of 4 years between invention (1955) and patent grant (1959)	– Positive relationship between patents granted and sales growth – Patents granted have a positive impact on profits via sales increases
Comanor and Scherer (1969)	57 firms from pharmaceutical industry	– Patent applications (1952-1957); patents granted (1955-1960) – Sales in the first 2 years after market introduction (1955-1960)	– Cross-section analyses – Time lag of 3 years between patent applications and first commercial use – Correlation analyses	– Positive relationship between patent applications, granted and sales – Larger influence of patent applications on sales
Griliches et al. (1991)	340 firms (USA)	– Successful patent applications (1970-1980) – Market value (1973-1980)	– Panel analyses (fixed effect) – Unexpected patent applications as the difference between present and predicted patent applications	– No influence of unexpected patent applications on the market value – Present and past patent applications explain 5% of the variance in market value changes
Austin (1993, 1995)	20 biotechnology firms (USA)	– 550 patents granted – Key patents (patent citations)	– Event study – Weighting of patent variables by quality indicators (key patents)	– Positive influence of patents granted on market value – Stronger influence of key patents on market value
Narin et al. (1987)	16 firms from pharmaceutical industry (USA)	– Patents granted (1975-1982) – Patents citations (1975-1982)	– Cross-section analyses – No time lag	– Positive relationship between patent citations per patent granted and financial performance – No relationship between the number of patents granted or of patent citations and financial performance

		– Patents citations per patent granted (1975-1982) – Concentration ratio	– Correlation analyses – Weighting of patent variables by quality indicators		
Ernst (1995)	50 firms from machine-tool industry (Germany)	– Multiple patenting indicators: number of patent applications, share of patents granted, share of valid patents, share of foreign patent applications, patent citation ratio (1979-1992) – Sales growth, sales per employee, development of sales per employee (1984-1992)	– Cross-section analyses – Time lag partly incorporated – Weighting of patent variables by quality indicators	– Firms with many patents of high quality are significantly more successful with regard to all three success variable – Firms with few patents of low quality are significantly less successful with regard to all three success variable	

Table 2.1: Empirical studies on the correlation between patents and firm's performance. Source: [Ernst, 2001, P.146-147].

In terms of methodological issues, studies by Ernst (1995), Comanor and Scherer (1969) and Scherer (1965) have included the influences of time lag between patent and subsequent sales. Other studies, i.e. Ernst (1995), Austin (1995, 1993) and Narin et al. (1987) indicated the importance and effect of patent quality on firm's performance.

However, patents do not always represent the optimal protection mode for technological innovations. According to Levin et al. (1987), the effectiveness of patents is found not constant across industries. In industries where rapid technological innovation takes place, so called fast-cycle industries, such as in the semiconductors, it is usually perceived that patents are not an effective means to protect innovations due to the relatively short average

technology life time and the long processing and approval periods from patent offices[10]. Patent protection becomes problematic when e.g. the next technology generation would be already on the market before the patent office would have even decided about the preceding technology's protection[11]. Companies in the pharmaceutical, chemical, steel, petroleum industries rate patents as effective protection of their inventions meanwhile in semiconductors, patents are rated as low effective. "Process technologies in the semiconductor market become obsolete every three years"[12] wherefore semiconductor firms tend to rely more on lead time, secrecy and manufacturing or design capabilities than patents to recoup investments in R&D.[13]

2.2. Time lag between patents and market entry

Before companies can reap the benefits of any patented inventions, usually a certain time lag appears until the final product is developed and launched (with the embedded patented technology) on the market. This time lag between patenting and the corresponding returns in terms of sales is illustrated in Figure 2.1 and consists of the product development processes and the time to launch the product in the market.

[10] Ref. Mansfield et al. (1981); Jennewein (2005), P.11-12, 165.
[11] Ref. Jennewein (2005), P.176-185.
[12] Ref. Neto and Gontes (2006), P.339-354.
[13] Ref. Ziedonis and Hall (2001), P.133-187.

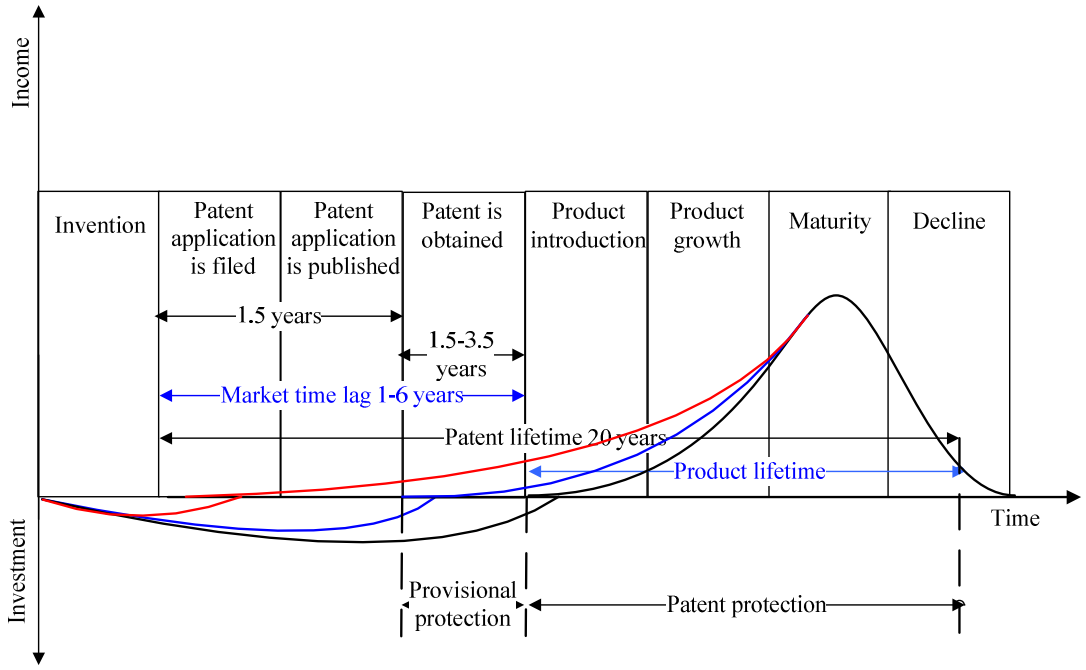

Figure 2.1: Conceptual model of relation between product life cycle and patenting process. Source: Self-construction according to [Granstrand, 1999, P.60, 74].

These time lags usually vary in different industries, but have to be considered and taken into account when analysing the patent influences on the economic performance. Ernst (1995, 2001) examined the relationship between patent applications and subsequent changes of company performance through case studies on machine-tool manufacturers and showed that national patent applications lead to sales increases with a time lag of two to three years after the priority year. Other studies, e.g. Comanor and Scherer (1969), Scherer (1965) have used time lags of three to four years in their empirical studies on the correlation between patents and sales growth on the firm level in different industries (refer Table 2.1). However, for the semiconductor industry or rather the optoelectronics no time lag analysis has been carried out so far, we have tested for the strongest correlation varying the time lag from one to six years. Since the semiconductor industry is generally characterized by rapid technological innovation and therefore categorized as a fast-cycle industry[14] this seems to be appropriate. In contrast

[14] Ref. Neto and Gontes (2006); Jennewein (2005); Ziedonis and Hall (2001); Grindley and Teece (1997).

product development in long-cycle industries e.g. pharmaceuticals, thus the time lag between patenting and corresponding sales revenues is normally between ten and 14 years[15].

3. Research question and methodological approach

In this study, we aim to better understand whether there is a relation between patenting activities of companies and their market success measured in terms of sales revenues. Sales revenues represent a more adequate indicator of the effects of patents on performance than profits, since sales reflect direct market feedback whereas firm profits can be determined by multitude of accounting measures depending on motives[16]. We focus on the fast cycle industry for flat panel displays (FPDs) and try to find answers for the following research questions (RQs): "What are the major FPD technologies?"; "who are the crucial innovators and key players in FPD industry?"; and "how and what are the relations among those innovators, the quantity of their annual patent applications and their economic success?" Due to the explorative characteristic of this research, multiple case studies were conducted which are often considered compelling and therefore the overall of the study is regarded as being more robust.[17]

In the first step, distinctive generations of global FPD technologies were mapped to identify today's most dominant technologies in this field. As a large number of different technologies were found, this study needed to be limited and emphasized to one widely diffused technology. The LCD and/or TFT LCD technology appeared as one of the most improved, commercially important and widely used technology in particular for small to large size

[15] Ref. Giovannetti and Morrison (2000), P.46.
[16] Ref. Hauschildt (1991); Ernst (2001), P.148.
[17] Ref. Yin (1989).

display applications. Between 2000 and 2005, the average global sales of TFT-LCD were about seven billion USD meanwhile other technologies together accounted for only 2.2 billion USD.[18]

In the second step, existing manufacturers of global FPD technologies were identified in order to identify key innovators in this field. In the beginning, 58 display manufacturers were identified as potential candidates for case studies. After focusing the TFT-LCD technology the list was reduced to 36 companies. The limited access to available data, further led to a second selection. Simply, non-publicly held companies were excluded since no sales figures for these were available. Finally, eight companies were selected that qualified as case studies for further investigation: LG Philips LCD (Korea), Samsung SDI Company Limited (Korea), Chi Mei Optoelectronics Corporation (Taiwan), International Business Machines Corporation (IBM, US), HannStar Display Corporation (Taiwan), Varitronix International Limited (Hong Kong), Planar Systems Incorporated (US) and, Densitron Technologies plc. (UK). The case studies comprise two manufacturers that produce primarily small to medium size displays, four manufacturers that produce mainly small to large size displays, and two manufacturers that produce medium to large size displays.

One criterion for selecting the case companies was to choose the top-runners of TFT-LCD patent applicants registered with the German Patent and Trademark Office (GPTO) and the EPO with force effect in Germany in 1996-2005. For this selection the total number of patent applications based on publication country code EP, DE and the patentees in the TFT-LCD field was taken into account. The keywords used to search the patents in database were TFT

[18] Ref. Hsieh (2005), P.5, 8.

and LCD. The scope of the patents includes the TFT-LCD manufacturing methods, driving methods, devices, drive circuits and substrates. Further, in this step for the selected case companies the number annual patent applications were collected. The patent data was collected using records from public (non-commercial) patent databases, in particular from the EPO database: http://ep.espacenet.com (worldwide). The search keywords were: (1) the company's or applicant's name, (2) title of display technology, (3) publication year and, (4) country code. Patent families, i.e. a patent that belongs to one invention but is applied for in several countries, are not investigated in this study. Thus, in order to avoid redundancy of the global number of inventions registered by a company, the analysis in this study was made by focusing on the national patent applications published in the countries of origin. Patents applied for in the home countries of the manufactures were selected because we assumed that the companies most probably protect all of their inventions in their home countries.

Furthermore, business figures were collected for the case companies in this second step. As a measure of success of the selected companies, sales revenues were collected from 1996 to 2005, either from publicly available annual reports or through direct company inquiries via telephone and email correspondences. Other helpful sources such as the companies' corporate website, annual reports, EDGAR system provided by United States Securities and Exchange Commission have been used in order to collect the companies' profile, milestones, product catalogues and business performance.

In the final step, the analysis was carried out. Therefore, the numbers of annual patent applications of the selected manufacturers were compared with their sales revenues preferably over a time period of ten years. The patent information used in this study refers to the published national patent applications. The data assessment of the correlation of annual patent

applications and subsequent changes in corporate performance was analysed by varying the time lag between one and six years for the performance years from 1996 to 2005. In a second analysis the possible linear relationship between patents and sales was tested using the Pearson's correlation coefficient written as:

$$\rho(X,Y) = \frac{\frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})\ (Y_i - \bar{Y})}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - \bar{X})^2} \bullet \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

ρ signifies the correlation coefficient. X and Y variables represent the independent and dependent variables. In this paper, X refers to the number of annual patent applications of the firm in period n, and Y refers to the corresponding sales revenues firm in period n, where n refers to the number of time periods. The interpretation of the correlation coefficient usually depends on the context and purposes of the phenomena of analysis therefore shall not be observed too strictly. Table 3.1 illustrates how the correlation coefficient has been interpreted in this study:

Correlation (ρ)	Negative	Positive
Weak	-0.29 to -0.10	0.10 to 0.29
Medium	-0.49 to -0.30	0.30 to 0.49
Strong	-1.00 to -0.50	0.50 to 1.00

Table 3.1: Interpretation of the size of a correlation.
Source: [Cohen, 1988].

As to mention one limitation to our approach, this study does not include an analysis of licensing behaviour between the companies, although this might be an important determinant for market success. Using our approach we are unable to show whether the case companies have been successful through the acquisition of licenses instead of performing own R&D activities and applying for own patents. Especially, we are not able to prove whether

companies that performed licensing have been more successful than companies that did not perform any licensing.

Another aspect that is not included in our analysis is the differentiation of product patents and process patents. Process patents protect process innovations, while product patents protect product innovations. Product innovations can be easily detected by competitors by analysing the final product (re-engineering) and can often be imitated by simple reproduction. Meanwhile, process innovations are often not easily detectable from the final product. According to Teece (2005), for protecting process innovations, other alternative protection modes e.g. trade secrets often represent the viable alternatives to patents. Since this matter is not investigated, we are unable to show whether companies reap more benefits from product patents than process patents and vice versa.

4. The industry under investigation: Flat panel display

Flat panel displays (FPDs) were not in significant use until the 1990s in products for large consumer markets. However, in recent years, the numbers of applications, in which displays are embedded, have increased.[19] Although FPDs are still relatively expensive they have gained particular importance because of their advantages in portability, weight, flat faceplate and thin profile. Since users demand better performance, technical progresses have been made in many areas to fulfil the demand such as light weight, thin, low power consumption, fast response time, large viewing angle, high brightness and resolution.

[19] Ref. Wisnieff and Ritsko (2000), P.409.

The FPD industry as part of the optoelectronics industry belongs to the semiconductors division and electronics as a whole. Total sales of FPD have significantly increased between 1998 and 2005 with an average growth rate of 33.48%. The largest share with about 31% of FPD revenues are generated by computer monitors, followed by mobile phones accounting for 18%, LCD televisions with 14% and notebooks with 12%.[20]

Databeans (2006) predicts that the optoelectronics industry will grow annually until 2011 with an average annual growth rate of about 14%, while the average annual growth rate for overall semiconductors within the same period is expected to be about 10% (Table 4.1).

	2005	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**	**'05-'11 CAGR**
Optoelectronics	15.1	20.1	22.2	27.3	30.3	32.5	38.0	
% Optoelectronics	-	24.88%	9.46%	18.68%	9.90%	6.77%	14.47%	14.03%
Total	226	259	293	307	355	383	423	
% Total	-	12.74%	11.60%	4.56%	13.52%	7.31%	9.46%	9.87%

Table 4.1: Databeans: a market study. Semiconductors worldwide turnover forecast (billion USD).
Source: Self-construction according to: [Markt & Technik, 5/2006, P.3].

For flat displays, several sub-technologies are available but a comparison of features in various FPDs technologies reveals that LCDs are the most promising for small to medium size direct-view displays. LCDs satisfy a wide variety of requirements not only in size but also resolution, brightness, etc. and became the quasi standard in multifunction and multimedia equipment.[21]

After the idea of using liquid crystal materials for display applications, probably first conceived in 1963 in Princeton, New Jersey, intensive R&D was carried out on applications of liquid crystals in the United States, Europe, and Japan. In 1970s, the activity in the liquid

[20] Ref. Hsieh (2005), P.6.
[21] Ref. Uchida (1992), P.10.

crystal research increased enormously and led to the first major applications, the 12x12 inch displays for digital watches and calculators.[22]

In the following decades further technical developments resulted in a wide range of applications and the development of several different sub-technologies. In the last decade the thin film transistor (TFT) technology has constantly increased the spectrum of applications and constantly gained the largest market share. Table 4.2 shows the technology leader of the TFT-LCD technology based on the share of total patent applications registered with the GPTO and EPO.

Applicants	**Home country**	**Approximate Σ no. TFT LCD patent applications in % (search keyword: TFT LCD)**
Samsung Group (Samsung Electronics, Samsung Display Devices, Samsung SDI)	KR	21.74%
LG Group (LG Electronics, LG Philips LCD, LG Semiconductor)	KR	13.04%
IBM Corp.	US	8.70%
Koninklijke Philips Electronics N.V.	NL	7.25%
Matsushita Electric	JP	5.80%
Sanyo Electric Co.	JP	5.80%
Hitachi Ltd.	JP	4.35%
Others		33.34%

Table 4.2: Front-runners for "DE-EP" TFT LCD patent applicants, year 1996-2005. Sources: GPTO and EPO database.

Table 4.2 shows that from a technological perspective the leading seven manufacturers own together almost 70% of the whole patents for the TFT-LCD technology. The two leading manufacturers, both based in Korea, own 1/3 of the patents. Furthermore, noteworthy seems the fact that only one of the top seven manufacturers comes from Europe (Philips Electronics,

[22] Ref. Castellano (1992), P.10.

NL), one from the US (IBM) and three companies are from Japan (Matsushita, Sanyo and Hitachi). In total, five out of the top manufacturers are from Asia.

A market analysis by iSuppli (2006) shows that in the third quarter of 2005, the business of large size TFT-LCD grew "extremely pleasing for the manufacturers". According to iSuppli, in 2005 the worldwide turnover of TFT-LCD reached 11.89 billion USD, while a study by DisplaySearch (2006) even raised the number up to 12.4 billion USD. Table 4.3 shows the ranking of the TFT-LCD manufacturers based on the sales items in 2005. LG Philips, a Korean based firm ranks first with 21.4%, followed by Samsung (Korea) with 20.9%, AU Optronics (Taiwan) with 14.5%, Chi Mei Optoelectronics (Taiwan) with 11.8% and Chunghwa Picture Tubes (Taiwan) with 7.3%. These five companies together accounted for a total of almost 75% of the total market volume.

	Country	2005	Q4 / 2005	Q3 / 2005	Q2 / 2005	Q1 / 2005
LG. Philips LCD	KR	21.4%	20.1%	21.3%	22.5%	22.4%
Samsung	KR	20.9%	20.7%	21.2%	20.6%	21.2%
AU Optronics	TW	14.5%	15.3%	14.2%	14.1%	14.2%
Chi Mei Optoelectronics	TW	11.8%	12%	11.8%	11.3%	12.1%
Chunghwa Picture Tubes	TW	7.3%	7.5%	7.3%	7.4%	6.7%
Others	-	24.1%	24.4%	24.2%	24.2%	23.4%

Table 4.3: The largest TFT LCD manufacturers: market share based on sales items in 2005.
Sources: [Markt & Technik, 4/ 2006, P.22]; [Segundo, 2006, P.66].

5. Findings

The following figures provide an overview of the surveyed companies, LG Philips (Korea), Samsung SDI Company Limited (Korea), Chi Mei Optoelectronics Corporation (Taiwan), International Business Machines Corporation (IBM, US), HannStar Display Corporation

(Taiwan), Varitronix International Limited (Hong Kong), Planar Systems Incorporated (US) and, Densitron Technologies plc. (UK). These companies applied for a total of 15,180 patents published in their home countries between 1996 and 2005.

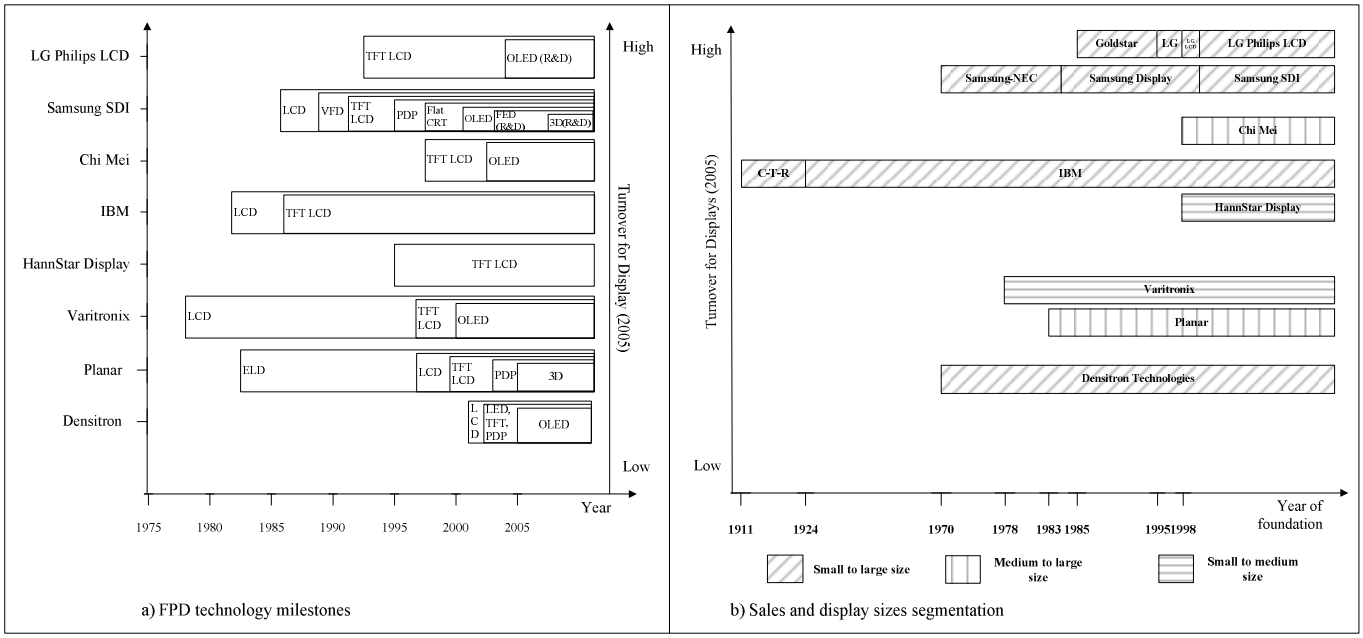

Figure 5.1: Overview of case companies.
Sources: [Corporate annual reports and website].[23]

According to the companies main products, which impact the characteristics of the company in the industry, the case companies were classified into three segments: (1) companies that produce small to large, (2) medium to large and (3) small to medium displays. Figure 5.1.a shows the core technology milestones from the case companies. The x-axis illustrates approximately the years when the companies began to develop certain technologies. The left y-axis indicates the companies and the right y-axis indicates approximately the sales revenues in 2005. E.g. Chi Mei in overall has developed two different technology platforms: TFT LCD which began approximately in 1998 and OLED approximately in 2003. Chi Mei gained relatively high revenues in 2005 ranking behind LG Philips and Samsung SDI. Figure 5.1.b

[23] LG. Philips, Samsung SDI and IBM have changed their corporate names several times in the earlier years (refer Figure 5.1.b).

illustrates the companies' performance. The x-axis indicated the years when the companies were founded and the y-axis shows the sales revenues in 2005.

Looking at the sales revenues in 2005, it appears that LG Philips, who produces small to large size displays, ranks first, followed by Samsung, Chi Mei, IBM, HannStar, Varitronix, Planar and Densitron. Noteworthy seems that in both figures 'new-comers' such as Chi Mei and HannStar have gained relatively high sales revenues in a short period of time, although they did not participate in the development of many different technologies.

As described in chapter 3, the analysis of the case companies was done based on a comparison of two variables, annual patent applications and sales revenues. Furthermore, the analysis was carried out multiple times for time lags between one and six years each. In addition we examined the possible linear correlation using a Pearson statistical test.

The correlation test was performed in two data sets, i.e. for individual firm and all firms. The coefficient for all firms was taken from the average value. The results were expected to indicate the strongest correlation for that time lag that equals the market lead time of the companies. Table 5.1 presents the correlation coefficient of annual patent applications and sales revenues for all data sets of the eight firms covering a period of ten consecutive years from 1996 to 2005[24].

[24] Since three firms (Chi Mei, HannStar and LG Philips) are relatively newly established or originated through mergers between 1998 and 1999, the data was only available from 1999 onwards. In the case of Densitron, data was available from 2001 onwards. Due to the difference in the available data, the coefficient could not have been calculated for all companies over all years in particular for the test above three years time lag.

ρ	**1 year lag**	**2 years lag**	**3 years lag**	**4 years lag**	**5 years lag**	**6 years lag**
All firms	**0.67**	**0.75**	**0.82**	**0.89**	**0.97**	**0.97**
LG Philips LCD	**0.97**	**0.94**	**1.00**			
Samsung SDI	**0.82**	**0.85**	**0.83**	**0.90**	**0.52**	0.19
Chi Mei	**0.95**	**0.88**	*-1.00*			
IBM	*-0.60*	*-0.66*	*-0.69*	-0.22	-0.19	0.32
HannStar	**0.80**	**0.72**	**0.96**	**1.00**		
Varitronix	0.00	0.00	0.00	0.00	0.00	0.00
Planar	0.23	0.25	0.08	-0.18	-0.03	**0.79**
Densitron	0.38	0.00	0.00			
Strong (+) %	**55.56%**	**55.56%**	44.44%	50.00%	40.00%	40.00%

Table 5.1: Correlation coefficient of the case companies.

The results in Table 5.1 indicate that seven out of eight firms show a relationship between annual patent applications and sales growth. Three firms (LG Philips, Samsung SDI and HannStar) show a constant positive relationship. Four firms (Chi Mei, IBM, Planar and Densitron) show a positive, negative as well as no relationship for different depending on the time lag. Varitronix shows constantly no relationship (coefficient $\rho = 0$).

The interpretation of positive and strong relationship is indicated by $\rho = 0.50 - 1.00$ (refer Table 3.1). It appears that four out of eight firms, i.e. LG Philips, Samsung SDI, Chi Mei and HannStar show the strongest relationship in a time lag between one and two years (55.56%).

Based on these results, the next three figures illustrate the relationship of annual patent applications and sales revenues with a fixed time lag of two years. Figure 5.2 compares the sales revenues in 2005 with patents applications in 2003. Figure 5.3 compares sales revenues

in 2004 and patent applications in 2002, and Figure 5.4 compares sales revenues in 2003 and patent applications in 2001. In the following three figures, the numbers of annual patent applications published in each firms' home countries are illustrated by a line. The sales revenues from the individual firms are illustrated by bars. The bar charts are filled with three different line patterns. Those line patterns represent the display size segmentation. The vertical lines represent medium to large size display, whereas the horizontal lines represent small to medium and diagonal lines represent small to large. s-axis shows the companies' names, the left y-axis the number of annual patent applications published in the companies' home countries in year 2003, the right y-axis shows sales revenues in million USD gained by companies in year 2005.

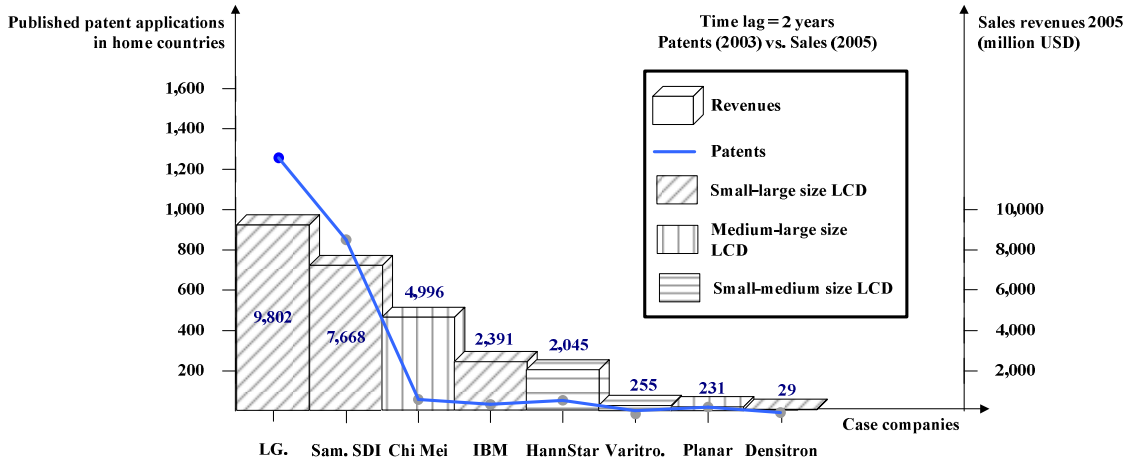

Figure 5.2: Case companies: patents versus sales, 2005.

Figure 5.2 shows that two companies, LG Philips and Samsung SDI had the highest sales revenues in 2005. Sales revenues of LG Philips accounted for 9,802 million USD and of Samsung SDI sales revenues were 7,668 million USD. Furthermore, both of them applied for the highest numbers patents in LCD and/or TFT LCD fields. In 2003, LG Philips applied for 1,220 patents and Samsung SDI for about 831 patents. The figure shows clearly a relation between annual patent applications and sales revenues, when comparing each for the eight

case companies. The companies with a higher number of patent applications indicate higher sales revenues while the companies with lower number of patent applications also gained lower sales revenues, i.e. Chi Mei applied for 54 patents, IBM for 26 patents, HannStar for 54 patents, Varitronix applied for zero patents, Planar applied for three patents and Densitron for zero patents.

However, the results are not completely convincing. Contradictory to LG Philips and Samsung SDI, IBM applied for fewer patents compared to HannStar, and Varitronix applied for fewer patents compared to Planar, however they gained higher revenues compared to the companies which applied for more patents. Further noteworthy is the case of Varitronix and Densitron, both companies applied for zero patents in the same year nevertheless Varitronix gained almost nine times higher sales revenues than Densitron.

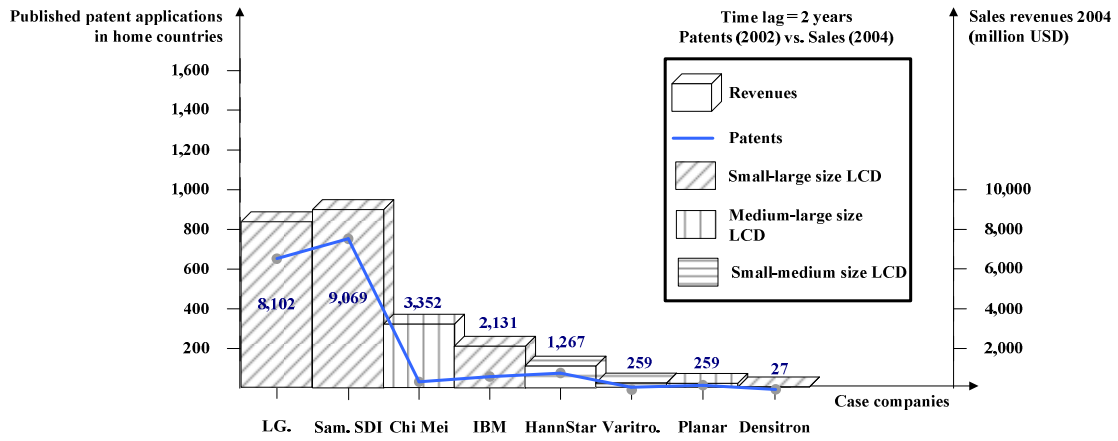

Figure 5.3: Case companies: patents versus sales, 2004.

Comparing the number of annual patent applications in 2002 with sales revenues in 2004, Figure 5.3 indicated similar results as Figure 5.2. LG Philips and Samsung SDI still show the highest sales revenues. The sales revenues of LG Philips reached 8,102 million USD and for Samsung SDI reached 9,069 million USD in 2004. Both of them gained as well applied for

the highest number of patent. In 2002 LG Philips applied for 696 patents and Samsung SDI for 827 patents in LCD and/or TFT LCD fields. Comparing this figure with Figure 5.2 shows that Samsung SDI now ranks first in regard to the number of annual patent applications. Following this change, sales revenues of Samsung SDI are as well higher than LG Philips.

As in Figure 5.2, the case companies with lower number of patent applications have also gained lower sales revenues, i.e. in year 2002 Chi Mei applied for about five patents, IBM for 34 patents, HannStar for 55 patents, Varitronix did not applied for any patents, Planar for four patents and Densitron for zero patents.

In a similar way like in Figure 5.2, besides this positive relationship Figure 5.3 shows also two contradictory cases. Chi Mei, although applied for fewer patents than IBM and HannStar, Chi Mei nevertheless gained higher revenues compared to them. Further, HannStar applied for more patents compared to IBM and Chi Mei however gained lower revenues. The same applies to the case of Varitronix and Densitron, both companies applied for zero patents, in the same year nevertheless Varitronix gained almost ten times higher revenues compared to Densitron. Furthermore noteworthy are the cases of Varitronix and Planar. Although Varitronix did not apply for any patents, its sales revenues where approximately as high as sales revenues of Planar, although Planar has applied for more compared to Varitronix.

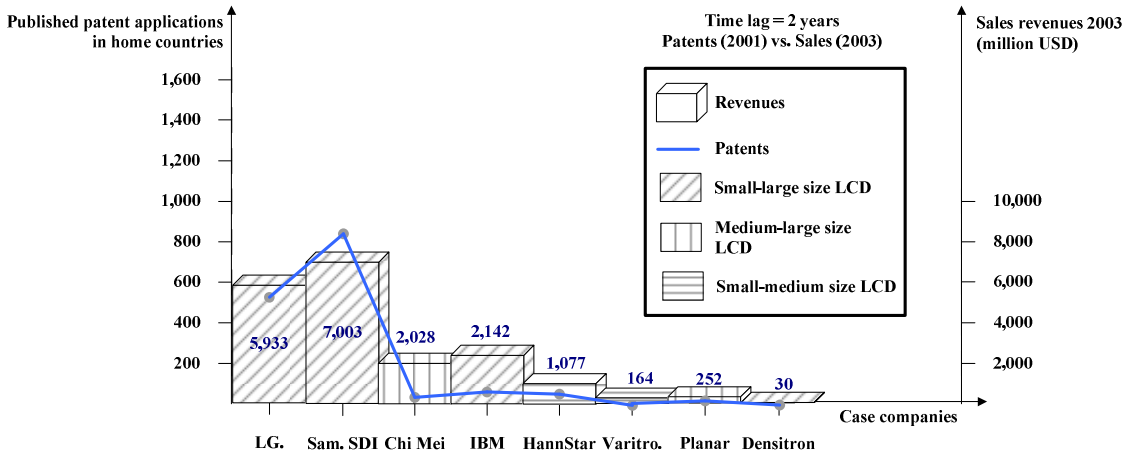

Figure 5.4: Case companies: patents versus sales, 2003.

Figure 5.4 again confirms the results shown in Figure 5.3 and Figure 5.2. LG Philips and Samsung SDI still had the highest sales revenues. Sales revenues of LG Philips reached 5,933 million USD and from Samsung SDI 7,003 million USD in 2003. In addition they also applied for the largest amount of patents in LCD and/or TFT LCD fields. LG Philips applied for 513 patents and Samsung SDI for 879 patents.

Samsung SDI applied for more patents than LG Philips. Similarly, the sales revenues of Samsung SDI were higher than from LG Philips. In general, the case companies that applied for fewer patents also raised lower sales revenues. In 2001 Chi Mei applied for seven patents, IBM applied for 34 patents, HannStar for 29 patents, Varitronix for zero patents. Planar applied for five patents and Densitron for zero patents. Alike in Figure 5.2 and Figure 5.3, Figure 5.4 shows as well one contradictory case. Although HannStar applied for more patents than to Chi Mei, HannStar gained lower revenues. The same phenomena applied for the cases of Varitronix and Densitron. Both companies did not apply for any patents, nevertheless Varitronix gained almost six times higher revenues compared to Densitron.

Based on the findings in Figure 5.2, Figure 5.3 and Figure 5.4, the bottom line is that:

- Companies, which have constantly applied the largest amounts of patents, were as well proven to be the most successful companies in terms of sales (LG Philips and Samsung SDI).
- Companies, which have applied more patents, have as well succeeded to gain high sales revenues (Chi Mei and IBM).
- Companies, which have applied fewer patents, nevertheless gained higher revenues compared to the companies with more patents and vice versa (in 2005 Varitronix versus Planar; IBM versus HannStar, in 2004 Chi Mei versus IBM and HannStar, in 2003 Chi Mei versus HannStar).
- Varitronix did not apply for any patents and nevertheless was able to gain the same level of sales revenues as the company with slightly more patents.
- Densitron, which has constantly applied the smallest amounts of patents, was as well proven to be the least successful company in terms of sales.

Comparing the results illustrated in the previous three figures, the case companies can be categorized. The number of patents can be grouped into three categories. A 'high level' of patent activity means above 500 applications per year. A 'moderate level' of patent activity applies to a range from 30 to 500 applications per year and a 'low level' of patent activity represents annual patent applications with quantity between below 30 applications. In a similar manner, the success level of the case companies can be grouped into four categories. An 'extreme high level' represents annual sales above 5,000 million USD, 'high level' means annual sales within range between 1,000 and 5,000 million USD. A 'moderate level' represents annual sales within range 100 to below 1,000 million USD, and a 'low level' represents sales below 100 million USD. Based on those results, the relevancies found

between annual patent applications and sales revenues (total z = 8) is summarized in Table 5.2.

No of patent applications (annual)	**Success level (annual sales revenues in million USD)**	**Surveyed companies (z)**
High (> 500)	Extreme High (> 5,000)	z = 2
Moderate (30 - 500)	High (1,000 - 5,000)	z = 3
Low (0 - below 30)	Moderate (100 - below 1,000)	z = 2
Low (0 - below 30)	Low (< 100)	z = 1

Table 5.2: Case companies: patents versus success level.

It appears in the findings that out of the eight case companies in this study, two companies fall into the 'high number' group of annual patent applications and achieved 'extreme high' success. Three companies had a 'moderate number' of annual patent applications and achieved 'high success' level. Two companies had a 'low number of annual patent application' and achieved 'moderate success' level and one company with 'low annual patent applications' and 'low success' level.

6. Conclusions and future research

Mapping distinctive generations of flat panel display (FPD) technologies, it is found that the liquid crystal display technology (LCD) and in particular the thin film transistor (TFT) sub-technology is currently the most advanced, commercially important and widely used technology for small to large display applications.

The identifying of leading manufacturers of these technologies showed that mostly Asian manufacturers dominate the FPD industry. LG Philips (Korea), Samsung SDI Company Limited (Korea), Chi Mei Optoelectronics Corporation (Taiwan), International Business Machines Corporation (IBM, US), HannStar Display Corporation (Taiwan), Varitronix

International Limited (Hong Kong), Planar Systems Incorporated (US) and Densitron Technologies plc. (UK) were analysed in this study. These companies have long records in innovation and strong patent portfolios in the TFT-LCD fields.

Following the aim of our research to explore the relation between patenting and market success, the results of this study in this short-cycle optoelectronics industry, respectively the semiconductor industry clearly indicate a certain relationship between the number of annual patent applications and economic success of companies. Our study has shown that the companies, which aggressively patent are the most successful companies in terms of sales and vice versa. The results are particularly interesting, since they appear to be contradictory to the results from prior studies. Commonly in short-cycle industries patents are perceived to be less important than trade secrets and trademarks. Although this might be the case as well in the industry of analysis in this study, one cannot dismiss the fact that patents definitely have certain relevance. One would question, why companies spend enormous amount of money on filing patent applications, if this would not be the case.

Analysing the time lag between patent applications and subsequent sales in the TFT-LCD industry, our results show the strongest positive relationship between one and two years. Interpreting these results in the context of the company size, one could suspect that large companies usually have more asset availability to invest, to continuously perform own R&D activities and keep up with the state-of-the-art technologies. As a consequence these might file more applications in a shorter time period. Meanwhile we found that small players in the industry, or rather young companies generally apply for a lower number of patents.

From these results, one could generally conclude that patents help to increase economic returns in business enterprises in the optoelectronics industry. The correlation analysis further proves this relationship. The results are positive for most of the firms even when tested with different time lags. Our analysis showed further that if the number of patent applications increased, the sales revenues increased as well, and vice versa. Another interesting fact found in the study is, most of the case companies tend to protect their inventions in their countries of origin. This is shown from a high amount of patent applications published in their home country code.

However, our results show certain restrictions. The pure quantitative amount of patent applications does not seem to be the only factor determining the success of the companies in the optoelectronics industry. One could suspect that the quality of the patent portfolio has a further relevance, i.e. small but strong patent portfolios may as well influence the success or other success factors exist (e.g. licensing). Our findings indicate that in some cases, companies did not own many patents and nevertheless they were able to capture relatively high sales revenues. This phenomenon might point to some additional factors influencing the market behaviour, which we were not able to capture with our study. For instance activities such as license agreements, cooperative R&D agreements and technology transfers, or general strategies, which help to speed up and to improve the innovation time through collaborations with the leading firms. Other facts that would influence the revenues are the product portfolios and segmentations e.g. that colour TFT-LCDs might have a higher sales price than standard LCD displays because of better features and qualities, or large TFT LCD panels have a higher sales price than small TFT LCD panels.

Area for discussion and possible future research

The present study is subject to constraints that prompt further research work. Throughout the study, questions appeared that could not yet be answered sufficiently, but are relevant to fully understand the dynamics in this industry. A further subject of research would be to question the patent and licensing strategies and other means used by the new comers to successfully commercialize their products and gain success in the market within a relatively short period of time. In the case of 'incumbents' it would be relevant to understand how these manage their patenting activities or strategies so that they are able to retain as front-runners.

Our approach of this study refers to annual patent applications. A further variation of this study would be to analyse how the results would change if the number of granted patents or patent families would have been analysed. Furthermore, another interesting theme would be to analyse if the results would change when the sales variable is extended to other corporate performance indicators such as profits or if the results would show different trends when referring to profits instead of sales.

In the present study, an extensive review of the patent literature reveals that further research is needed into the analysis of the correlation between patents and firm performance as in particular the time lag analysis has not received sufficient attention in studies examining the correlation between those variables.

7. References

Auger, C.P. (Ed.) (1992): "Information sources in patens", London: Bowker-Saur.

Austin, D.H. (1995): "The power of patents", in: Resources, No.119, P.2-5.

Austin, D.H. (1993): "An event-study approach to measuring innovative output: the case of biotechnology", in: The American Economic Review, Vol.83, No.2, P.253-258.

Breitzman, A.F., Mogee, M.E. (2002): "The many applications of patent analysis", in: Journal of Information Science, Vol.28, No.3, P.187-205.

Brockhoff, K.K. (1992): "Instruments for patent data analyses in business firms", in: Technovation, Vol.12, No.1, P.41-58.

Castellano, J.A. (1992): "Handbook of display technology", California: Academic Press, Inc.

Chi Mei Optoelectronics (2005); (2004); (2003); (2002): Annual report, Tainan, Taiwan.

Cohen, J. (1988): "Statistical power analysis for the behavioural sciences", Hillsdale, NJ: Lawrence Erlbaum Associates.

Comanor, W.S., Scherer, F.M. (1969): "Patent statistics as a measure of technical change", in: Journal of Political Economy 77, P.392-398.

Densitron Technologies (2005); (2004); (2003); (2002): Annual report, London.

Dreßler, A. (2006): "Patente in technologie-orientierten Mergers & Acquisitions: Nutzen, Prozessmodell, Entwicklung und Interpretation semantischer Patentlandkarten", Wiesbaden, Deutscher Universitäts-Verlag.

EPO (2005): "Facts and figures", Munich.

EPO (2005a): "Patent information: patents – knowledge for everyone", Munich.

Ernst, H. (2001): "Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level", in: Research Policy, Vol.30, No.1, P.143-157.

Ernst, H. (1995): "Patenting strategies in the German mechanical engineering industry and their relationship to firm performance", in: Technovation, Vol.15, No.4, P.225-240.

Giovannetti, G.T., Morrison, S.W. (2000): "Convergence: the biotechnology industry report", Ernst & Young.

Granstrand, O., (1999): "The economics and management of intellectual property: towards intellectual capitalism", Cheltenham: Edward Elgar Publishing Limited.

Granstrand, O., Patel, P., Pavitt, K. (1997): "Multi-technology corporations: why they have "distributed" rather than "distinctive core" competencies", in: California Management Review, Vol.39 No.4, P.8-25.

Griliches, Z., Hall, B.H., Pakes, A. (1991): "R&D, patents, and market value revisited: is there a second (technological opportunity) factor?", in: Economics of Innovation and New Technology, No.1, P.183-201.

Griliches, Z. (1990): "Patent statistics as economic indicators: a survey", in: Journal of Economic Literature, Vol.28, No.4, P.1661-1707.

Grindley, P.C., Teece, D.J. (1997): "Managing intellectual capital: licensing and cross-licensing in semiconductors and electronics", in: California Management Review, Vol.39, No.2, P.8-41.

Hall, B.H., Ham, R.M. (1999): "The patent paradox revisited: determinants of patenting in the US semiconductor industry, 1980-94", in: National Bureau of Economic Research working paper No.7062, Massachusetts.

HannStar (2005); (2004); (2003); (2002); (2001); (2000): "Annual report", Taiwan.

Hauschildt, J. (1991): "Zur Messung des Innovationserfolgs", in: Zeitschrift für Betriebswirtschaft, Vol.61, No.4, P.451-476.

Hsieh, David (2005): "Flat panel display market outlook", in: Display Search, 5.11.2005, P.1-41.

Idris, K. (2003): "Intellectual property: a power tool for economic growth", in: WIPO publication, No.888.1, 2nd edition, P.1-20.

International Business Machines (2005); (2004); (2003); (2002); (2001); (2000); (1999); (1998); (1997); (1996): "Annual report", New York.

Jennewein, K. (2005): "Intellectual property management: the role of technology-brands in the appropriation of technological innovation", Heidelberg: Physica-Verlag.

Kim, L. (1997): "The dynamic of Samsung`s technological learning in semiconductors", in: California Management Review, Vol.39, No.3, P.86-100.

Kuei-Kuei, L., Mei-Lan, L., Shu-Min, C. (2006): "Research trends on patent analysis: an analysis of the research published in library's electronic databases", in: Journal of American Academy of Business, Vol.8, No.2, P.248-253.

Levin R.C., Klevorick A.K., et al. (1987): "Appropriating the returns from industrial research and development", in: Brookings Papers on Economic Activity, 3, P.783-820.

LG. Philips LCD (2005); (2004); (2003); (2002); (2001): "Annual report", Seoul.

Macdonald, S., Lefang, B. (2003): "Worlds apart - patent information and innovation in SMEs", in: Intellectual Property and Innovation Management in Small Firms, P.123-143, London.

Mansfield, E. (1986): "Patents and innovation: an empirical study", in: Management Science, Vol.32, No.2, P.173-181.

Mansfield, E., Schwartz, M., et al. (1981): "Imitation costs and patents: an empirical study", in: The Economic Journal 91, P.907-918.

Mogee, M.E., Kolar, R.G. (1994): "International patent analysis as a tool for corporate technology analysis and planning", in: Technology Analysis and Strategic Management, Vol.6, No.4, P.485-503.

Mogee, M.E. (1991): "Using patent data for technology analysis and planning", in: Engineering Management Review, P.46-51.

N, N. (2006): "Databeans: Marktstudie zu 2006, Halbleiter wieder im Steigflug", in: Markt & Technik, 03.02.2006, No.5, P.3.

N, N. (2006): "Consumer-Anwendungen treiben den LCD-Markt an", in: Markt & Technik, 27.01.2006, No.4, P.22.

Narin, F., Noma, E., Perry, R. (1987): "Patent as indicators of corporate technological strength", in: Research Policy, Vol.16, No.2-4, P.143-155.

Neto, J.A., Gontes, C.B.V. (2006): "Evaluation of technological change in the Brazilian semiconductor industry", in: International Journal of Technology Marketing, Vol.1, No.3, 2006, P.339-354.

Pavitt, K. (1988): "Uses and abuses of patent statistics", in: Handbook of Quantitative Studies of Science and Technology, Amsterdam, P.509-536.

Pavitt, K. (1985): "Patent statistics as indicators of innovative activities: possibilities and problems", in: Scientometrics, Vol.7, No.1-2, P.77-99.

Pavitt, K. (1979): "Using patent statistics in science indicators", in: The Meaning of Patent Statistics, National Science Foundation, Washington.

Planar Systems (2005); (2004); (2003); (2002); (2001); (2000); (1999); (1998); (1997); (1996): "Annual report", Oregon.

Samsung SDI (2005); (1999); (1998); (1997); (1996): "Sustainability report", Seoul.

Scherer, F.M. (1965): "Corporate inventive output, profits and growth", in: Journal of Political Economy, Vol.73, No.3, P.290-297.

Segundo, E. (2006): "TFT-LCDs ab 10 Zoll: 10-Milliarden-Dollar-Marke geknackt", in: Markt & Technik, 20.01.2006, No.3, P.66.

Teece, D.J. (2005): "Technology and technology transfer: Mansfieldian inspirations and subsequent developments" in: Essays in Honor of Edwin Mansfield: the economics of R&D, innovation, and technical change, Link, A.N. (Ed.), Scherer, F.M. (Ed.), New York.

Teece, D.J. (2003): "The strategic management of technology and intellectual property", in: The Oxford Handbook of Strategy: a strategy overview and competitive strategy, Faulkner, D.O. (Ed.), Campbell, A. (Ed.), Vol.1, P.132-166, New York.

Trajtenberg, M. (1999): "Innovation in Israel 1968-97: a comparative analysis using patent data" in: National Bureau of Economic Research working paper No.7022, Massachusetts.

Uchida, T. (1992): "Present and future trend of liquid crystal devices", in: Display Technologies, Chen, S. (Ed.), Wu, S. (Ed.), Proceedings SPIE the international society for optical engineering, Vol.1815, P.10-17, Bellingham, Washington.

Varitronix (2005); (2004); (2003); (2002); (2001); (2000); (1999); (1998); (1997); (1996): "Annual report", Hong Kong.

Wisnieff, R.L., Ritsko, J.J. (2000): "Electronic displays for information technology", in: IBM Journal of Research and Development, Vol.44, No.3, P.409.

Yin, R.K. (1989): "Case study research: design and method", California: Sage Publications, Inc.

Ziedonis, R.H., Hall, B.H. (2001): "The effects of strengthening patent rights on firms engaged in cumulative innovation: insights from the semiconductor industry", in: Entrepreneurial Inputs and Outcomes: New Studies of Entrepreneurship in the United States, Libecap, G.D. (Ed.), Advances in the Study of Entrepreneurship, Innovation and Economic Growth, Vol.13, P.133-187, Kidlington, Oxford.