Journal of Informetrics 6 (2012) 131–139

Contents lists available at SciVerse ScienceDirect

Journal of Informetrics

journal homepage: www.elsevier.com/locate/joi

The relationships between the patent performance and corporation performance

Ke-Chiun Chang[a,*], Dar-Zen Chen[b], Mu-Hsuan Huang[c]

[a] School of Economics and Management, Wuhan University, Wuhan 430072, China
[b] Department of Mechanical Engineering, National Taiwan University, Taipei, Taiwan
[c] Department of Library and Information Science, National Taiwan University, Taipei, Taiwan

ARTICLE INFO

Article history:
Received 8 June 2011
Received in revised form 15 August 2011
Accepted 14 September 2011

Keywords:
Patent citations
H index
Essential patent index
Current impact index

ABSTRACT

This study utilizes panel regression model to explore the relationships between corporate performance and the patent performance measured from patent H index, current impact index (CII), and essential patent index (EPI) in the pharmaceutical company. The results demonstrate that patent H index and EPI have positive influences upon corporate performance. Furthermore, this study developed a classification for the pharmaceutical companies to divide them into four types, and provided some suggestions to them.

1. Introduction

Patents, serving as an important output indicator of research and development activities, are widely adopted in researches concerning relationship between patent counts and corporation performance (Bosworth & Rogers, 2001; Comanor & Scherer, 1969; Deng, Lev, & Narin, 1999; Scherer, 1965). However, they often fail to offer sufficient information regarding innovation output since that some enterprises may have only a few patents but with high influence, while others may have a lot of patents yet low in influence (Hirschey & Richardson, 2001; Park & Park, 2006). This phenomenon is also known as the skewed distribution of patent value which means that patents with high value and high influence only take a small portion of total patents (Park & Park, 2006; Schankerman & Pakes, 1986).

In light of this, many scholars suggest that patent citations could be used measure the influence of patent. The idea of measuring patent citations is based on the same base in Bibliometrics that the influence of certain publication could be measured by its citation. Therefore, patent citations could also be utilized as a measure of the technological quality and importance of the patent. Through patent citation analysis, fundamental or important patents could be identified in the sense that the more frequent the patent citations is, the higher influence the patent is of, or the more impact or important it possesses (Breitzman, Thomas, & Cheney, 2002; Deng et al., 1999; Narin, 1994; Trajtenberg, 1990).

Trajtenberg (1990) argues that the higher frequency of corporation patent citations is, the more probability that the patents may serve as the fundamental of future patented technology development, and the more influence on technological development it may resume which meantime also may implicate the higher value of the patent (Brown & Svenson, 1998; Jaffe, Trajtenberg, & Henderson, 1993; Narin, Hamilton, & Olivastro, 1997; Stolpe, 2002; Stuart & Podolny, 1996). Moreover, patent citations could also be used as the measure of corporation R&D output, innovation worth as well as corporation invention

* Corresponding author. Tel.: +86 27 68753177; fax: +86 27 68754150.
E-mail addresses: kechiun@gmail.com, dr.chang@whu.edu.cn (K.-C. Chang), dzchen@ntu.edu.tw (D.-Z. Chen), mhhuang@ntu.edu.tw (M.-H. Huang).

1751-1577/$ – see front matter
doi:10.1016/j.joi.2011.09.001

performance (Hagedoorn & Cloodt, 2003; Hall, Jaffe, & Trajtenberg, 2005; Lanjouw & Schankerman, 2004; Trajtenberg, 1990).

In researches regarding the relationship between patent performance and corporation performances, many scholars have confirmed the positive relation between patent citations and market value in many industries such as manufacturing, pharmaceutical as well as semiconductor industries (Chen & Chang, 2010; Griliches, 1990; Hall, Jaffe, & Trajtenberg, 2000; Hall et al., 2005; Lanjouw & Schankerman, 2004; Shane & Klock, 1997). Meanwhile, patent citations is also highly interrelated with profits and sales (Narin, Noma, & Perry, 1987). With patent counts and patent citations etc. as the indicator of corporation technological capacity, Deng et al. (1999) empirical study has further confirmed that the higher patent counts and patent citations are, the better corporation performance (stock return, market-to-book ratio) is. Besides, findings of Harhoff, Narin, Scherer, and Vopel (1999), and Harhoff, Schererc, and Vopeld (2003) also suggest positive relation between patent value and patent citations. Therefore, we can safely draw the conclusion that high patent citations also reflects high knowledge spillover and economic value (Chen & Chang, 2010; Griliches, 1990; Hall, 2000; Harhoff et al., 1999; Jaffe et al., 1993; Stolpe, 2002; Trajtenberg, 1990).

Based on the proposition that patent citations indicator demonstrates technological capacity quality of corporation, this study used three patent citations indicators – patent H index (Guan & Gao, 2009), current impact index (Breitzman & Narin, 2001), and essential patent index (Chen, Lin, & Huang, 2007) to explore their influences upon the corporate performance to fill the research gap. The structure of this paper is as follows: Section 2 would outline the literature review and hypothesis development; Section 3 described the methodology and measurement of this paper; Section 4 would discuss the empirical results; the final section was conclusions and implications of this study.

2. Literature review and hypothesis development

Hirsch (2005) proposes a new indicator H index as a measure of individual scientist research achievements which is defined as follows: "A scientist has index h if h of his or her N_p papers have at least h citations each and the other $(N_p - h)$ papers have $\leq h$ citations each (Hirsch, 2005). Just as the H index, Guan and Gao (2009) define the patent H index, the number h such that, for a general group of patents, h patents received at least h citations from later patents, while other patents received no more than h citations. Guan and Gao (2009) demonstrated that the patent H index is indeed an effective patent indicator for evaluating the technological capacity, quantity, and quality, or impact, for an assignee (Kuan, Huang, & Chen, 2011). Thus higher patent H index also means higher technological capacity, quantity, and quality, or impact. Therefore, this study implies the following hypothesis:

H1. Patent H index of corporation is positively associated with their performance.

Current impact index (CII) for a particular company is "calculated based upon the number of times patents issued this year cite the patents issued to the chosen company in each of the previous five years. Just as patent citations, high CII implicates high technological value or economic value of the patent (Deng et al., 1999). Empirical findings from Hirschey and Richardson (2001) and Hirschey, Richardson, and Scholz (2001), which is set in High-tech industry in Japan and the USA, suggest that CII is positively related to market value and there is also a positive relation between CII and stock performance (market-to-book ratio) (Thomas, 2001). Therefore, this study implies the following hypothesis:

H2. Current impact index (CII) of corporation is positively associated with their performance.

Essential patent index (EPI) was developed by incorporating information on who cited these patents and when these patents were cited. Namely, citations received from important assignees should represent higher impact and with different seniority should not be treated as the same, based on the assumption that both contribute to patent quality assessment (Chen et al., 2007). Therefore, Chen et al. (2007) used EPI for assessment of patent quality performance in industries in Taiwan such as semiconductor, computer systems, computer peripherals and parts industries. Chen et al. (2007) finding indicates that EPI serves as a better measure than patent counts index on assessing enterprise technological capacity. Therefore, this study implies the following hypothesis:

H3. Essential patent index (EPI) of corporation is positively associated with their performance.

As mentioned above, this study proposed three hypotheses to explore the influence of patent H index, current impact index (CII) and essential patent index (EPI) upon corporation performance.

3. Methodology and measurement

3.1. Sample and data collection

The firms selected are the top global sales of prescription drug as indicated by the 2010 Pharm Exec 50. After adjustments for extreme values and missing data, the final sample for analysis consists of 42 public firms and 555 firm-year observations. The panel data containing patent data and financial data of the sample spanned the period from 1996 to 2009. The financial data of this study were obtained from the COMPUSTAT database. The patent data of this study was gathered from the United States Patent and Trademark Office (USPTO). These patent data of this study had sufficient information about names of assignees, technical fields, and the issued dates and so on. Through the LexisNexis and Thomson Innovation database, patent data were collected at the consolidated level; that is, all patents assigned to the parent firm as well as consolidated, majority-owned subsidiaries of the parent firm are taken into account to assess the patent H index, CII, and EPI of the sample firms.

The panel data of this study containing patent data and financial data of the sample spanned the period of a decade from 1993 to 2009. In order to analyze the panel data, this study applied panel data models to verify the hypotheses in the research framework. Panel data combining the characteristics of time series and cross sections may have firm-specific effects, period-specific effects, or both. There are three types of panel data models: pooled regression model, fixed effect model, and random effect model (Greene, 2003). Solutions to problems of heterogeneity and autocorrelation are of interest among these three types of panel data models. Both intercepts and slopes of the pooled regression model have constant coefficients. In the pooled regression model that has neither a significant firm-specific effect nor a period-specific effect, we could pool all of the data and run an OLS regression model (Hsiao, 2003). Although there are often either firm-specific effects or period-specific effects, there are some occasions when both firm-specific effects and period-specific effects are not statistically significant. The fixed effect model assumes there are differences in intercepts across firms or periods, whereas the random effect model explores differences in error variances. The fixed effect model, also known as least square dummy variable (LSDV), removes all between-firm variance and thus controls for any time invariant unobserved heterogeneity among firms. Hence, the fixed effect model constrains the coefficients to be within-firm effects (Maddala, 1993). The random effect model considers the firm-specific effects as random variables, and it assumes that firm-specific effects are normally distributed throughout the population (Greene, 2003).

3.2. Measurement

- Corporation performance: This study used market value, sales and Return on Equity (ROE) as the proxy variable of corporation performance. Market value is generally estimated by the value which is the average stock price of a company in a given year multiplied by the number of its common stock shares outstanding.
- Patent H index: Assignee has patent index h if h of his or her N_p patents have at least h citations each and the other $(N_p - h)$ patents have $\leq h$ citations each (Guan & Gao, 2009).
- Current impact index (CII): The study defines CII of a company as follows:

$$CII_i \frac{100C_i/\sum_i C_i}{100K_i/\sum_i K_i} \tag{1}$$

where C_i represents the cited number of patents in a certain year, and company i produced from previous 5 years, K_i is the number of patents, company i produced during the past 5 years (Breitzman & Narin, 2001).
- Essential patent index (EPI):

$$\Psi_s = \prod_{a=1}^{A_s} \psi_{a,s}^{n_{a,s}} \tag{2}$$

where $\Psi_{a,s}$ is the company-weighted factor of assignee a which cite patent s, As is the total number of companies which cite patent s, and $n_{a,s}$ is the total cited times of patent s by company a.

$$W_{Z,q} = \frac{E_{z,q}^{-1}}{\sum_{q=0}^{Q_z} E_{z,q}^{-1}} \tag{3}$$

where $E_{z,q}$ is the total number of patents granted in year z which are cited in year $z+q$. The essential integration G_s is derived from the factor $W_{z,q}$ and Ψ_s, hence the equation is given by,

$$G_s = \sum_{q=0}^{q_{\max}} (W_{z,q} \times e_{s,z,q}) \times \Psi_s \tag{4}$$

where $e_{s,z,q}$ is the total cited times of patents s (granted in year z) in year $z+q$. Based on the essential integration G_s, this study refers to Chen et al. (2007) to define the essential patents as those ranked in the top 25% of the patents. The EPI of i company can be computed by its number of patents and number of essential patents as follow:

$$EPI_i = \frac{EPN_i/P_i}{0.25} \tag{5}$$

where EPN_i represent the number of essential patents which receive high essential integration scores owned by i company, P_i represent the number of patents owned by i company (Chen et al., 2007).
- Control variables: This study included a number of control variables in the empirical model that may influence a firm's performance: firm size and firm R&D spending. Firm size can demonstrate the economies and diseconomies of scale. According to Schumpeterian hypothesis, large firms are more likely to support innovation, because large firms can not

Table 1
Descriptive statistics and correlations.

Variables	Mean	S.D.	Min.	Max.	1.	2.	3.	4.	5.	6.	7.	8.
1. Market value	35,724.92	47,850.26	44.23	290,444	1							
2. Sales	9742.97	12,280.95	1.12	63,747	0.85**	1						
3. ROE	12.07	46.32	-990.38	100.79	0.17**	0.15**	1					
4. Patent H index$_{t-1}$	18.10	16.50	0	102	0.56**	0.61**	0.12**	1				
5. Current impact index$_{t-1}$	1	0.87	0	6.84	0.14**	0.16**	0.10**	0.33**	1			
6. Essential patent index$_{t-1}$	0.30	0.38	0	4	0.07**	0.07**	0.04**	0.14**	0.70**	1		
7. Total assets$_{t-1}$	14,504.44	20,856.40	11.55	123,684	0.75**	0.91**	0.09**	0.57**	0.09*	0.01**	1	
8. R&D expenditures$_{t-1}$	1261.24	1762.04	0.27	12,183	0.76**	0.89**	0.10**	0.61**	0.10*	0.01**	0.92**	1

* $p < 0.05$.
** $p < 0.01$.

Table 2
Results of panel fixed-effect model.

Variables	Market value	Sales	ROE
Intercept	−71,914.57** (−5.05)	−15,244.58** (−4.68)	81.11** (12.65)
Independent variables			
Patent H index$_{t-1}$	1247.08** (9.30)	437.83** (14.29)	0.18** (3.92)
Current impact index$_{t-1}$	−48.55 (−0.03)	518.40 (1.45)	0.12 (0.17)
Essential patent index$_{t-1}$	8758.27* (2.56)	1724.40* (2.20)	2.71* (1.97)
Control variables			
Firm size$_{t-1}$	8279.52** (3.99)	1816.72** (3.83)	0.61 (0.74)
R&D expenditures$_{t-1}$	1731.93 (0.90)	46.74 (0.11)	0.16 (0.23)
F-value	49.75	64.92	42.86
Log likelihood	−6198.10	−5402.03	−1386.41
R^2	0.86	0.89	0.87
Adjusted R^2	0.84	0.88	0.85
Number of groups	42	42	42
Number of observations	555	555	555
Baltagi test (*F* test)	23.80	25.93	32.75
Breusch–Pagan test (LM test)	1591.35	1249.50	1435.56
Hausman test	8.17	33.76	7.71

* $p < 0.05$.
** $p < 0.01$.

only invest more staff and resources in R&D, but exploit unforeseen innovations and cost-reducing innovations to make them more profitable such that they have scale economy in R&D. However, early studies also indicate that large firms can have less incentive to innovate. Therefore, to control size effect, firm size is measured by the logarithm of assets in this study. Besides, this study controlled for R&D expenditures by using the logarithm of annual research and development expenditure1 as a proxy.

4. Results

The descriptive statistics and correlation matrix of this study were showed in Table 1. According to Table 1, corporation performance (market value, sales, and ROE) is correlated with patent H index, CII, total assets, and R&D expenditures. This study explored the influence of patent H index, CII and EPI on their performance. The dependent variable of this study was market value, sales and ROE, and the independent variables were patent H index, CII and EPI, while the control variables were the R&D expenditures and firm size.

This study applied panel data models to verify the hypotheses in the research framework. There are three types of panel data models: pooled regression model, fixed effect model, and random effect model (Greene, 2003). There are three stages to determine which panel data models should be selected in this study. First, this study used Baltagi test (*F* test) to determine whether the pooled regression model or the fixed effect model should be selected as the empirical model (Greene, 2003). The result showed that the fixed effect model was better than the pooled regression model. Second, this study applied Breusch–Pagan test (LM test) to determine whether the pooled regression model or the random effect model should be selected as the empirical model (Greene, 2003). The result showed that the random effect model was better than the pooled regression model. Third, this study used Hausman test to determine whether the fixed effect model or the random effect model should be selected as the empirical model (Greene, 2003). The result showed that the fixed effect model was better

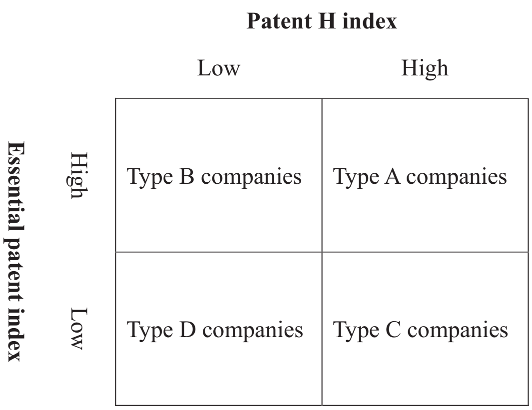

Fig. 1. The classification for the pharmaceutical firms.

than the random effect model in Table 2. Therefore, this study used the fixed effect model to verify the hypotheses in the research framework.

The empirical results of the fixed effect model in Table 2 indicated that patent H index and EPI were positively associated with its market value, sales and ROE. That meant that the higher the patent H index and EPI, the more was its market value, sales and ROE. Therefore, these two hypotheses, H1 and H3, were significantly supported in this study. However, Table 2 showed that the CII was not positively associated with its market value, sales and ROE. Hence, the hypothesis, H2, was not significantly supported in this study.

5. Conclusions and discussion

The objective of this paper was to investigate the influence of patent performance which were patent H index, CII and EPI upon corporation performance in the pharmaceutical industry. The results indicated that patent H index and EPI had a positively effect on the market value, sales and ROE.

This study finding out that patent H index and EPI were positively associated with firms' market value, sales and ROE in the pharmaceutical industry of global, this study developed a classification for the pharmaceutical companies based on two dimensions, patent H index and EPI, as shown in Fig. 1.

The *X*-axis of the classification in this study is the indicator of each firm's patent *h* index. Firm's patent H index can measure its technological capacity, quantity, and quality or impact. Because H1 is supported in this study, patent H index is positively related to corporate performance. This study used the median of patent H index to distinguish the pharmaceutical companies with high level of patent H index from those with low level of patent H index. The mean of patent H index in this study was 29.95.

The *Y*-axis of the classification in this study is the indicator of each firm's EPI. EPI of a firm can measure its technological capacity, technological value or economic value of the patent. Because H3 is supported in this study, EPI is positively related to corporate performance. This study used the median of EPI to distinguish the pharmaceutical companies with high level of EPI from those with low level of EPI. The mean of EPI in this study was 0.17.

Based on the classification above, this study divided the pharmaceutical companies into four groups: The characteristics of Type A companies, such as Pfizer or Novartis, include: high patent H index and high EPI. Type A companies are the ideal target of the companies of other types, because they don't need to improve their patent H index and EPI. The characteristics of Type B companies, such as AstrZeneca or Novo Nordisk, include: low patent H index and high EPI. This study suggested Type B companies should increase their patent H index. In addition, the characteristics of Type C companies, such as Amgen or Eli Lilly & Co., include: high patent H index and low EPI. This study suggested Type C companies should increase their EPI. Finally, the characteristics of Type D companies, such as Meda or Watson Pharmaceuticals, Inc., include: low patent H index and low EPI. Type D companies are the worst ones among the four types, because they need to increase their patent H index and EPI simultaneously or in sequence.

This research was conducted in the pharmaceutical industry. Future studies can undertake on other industries to explore the relevant topics, and compare to this study. Moreover, this study explored the influence of patent H index, CII and EPI, upon firms' market value, sales or ROE. Future studies can focus on other indicators to explore the relevant topics, and compare to this study. Finally, this study hoped that the research results can be beneficial to managers, researchers, or governments, and contributed to relevant studies and future researches as reference.

Acknowledgements

This work was supported by grants from the Fundamental Research Funds for The Central Universities of China (105273449).

Appendix A. The pharmaceutical companies of the sample and their means and standard deviations of the variables in the period 1993–2009

	Market value		Sales		ROE		Patent H index		CII		EPI		Total assets		R&D expenditures		Citations obtained/patent	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
ABBOTT LABORATORIES	62,474.66	21,073.09	17,304.44	7024.26	29.17	9.16	38.47	15.78	0.49	0.13	1.73	0.8	23,217.03	13,459.23	1875.94	920.82	0.22	0.12
ALCON INC	30,916.69	12,618.87	4746.49	1300.52	41.56	5.35	6.5	4.28	0.39	0.21	0.91	0.34	5830.84	1719.76	481.88	128.76	2.76	4.4
ALLERGAN INC	9116.81	6315.78	2044.68	1202.07	13.9	12.75	44.53	18.31	0.73	0.44	2.52	1.84	2829.33	2265.34	374.83	308.4	0.11	0.1
AMGEN INC	49,269.59	29,112.69	6991.11	5382.12	22.41	11.14	14.71	10.66	0.23	0.28	0.95	0.48	16,782.97	14,954.71	1789.57	1463.37	0.26	0.15
ASTELLAS PHARMA INC	19,603.29	4797.59	7842.72	2399.93	11.1	4.54	24	1.58	0.08	0.03	0.49	0.09	12,918.57	3100.11	1237.91	432.65	0.26	0.01
ASTRAZENECA PLC	60,796.78	21,663.9	19,285.52	8459.82	29.25	7.93	13.27	8.53	0.27	0.27	0.74	0.38	24,342.77	14,993.5	2959.88	1384.35	2.04	3.16
BAXTER INTERNATIONAL INC	21,270.37	9620.28	8547.06	2300.39	19.84	10.73	43.94	19.47	0.59	0.24	1.84	0.55	11,821.29	2870.83	568.71	189.96	0.13	0.09
BAYER AG	36,686.44	16,905.02	34,591.31	7536.11	8.42	6.74	13	12.08	0.32	0.22	0.9	0.33	51,152.41	17,784.74	2765.09	638.03	1.27	1.77
BIOGEN IDEC INC	12,737.95	5231.3	1872.03	1617.27	8.46	10.12	11.27	7.27	0.2	0.16	0.86	0.29	5964.86	3898.37	656.52	489.7	0.96	1.48
BRISTOL-MYERS SQUIBB CO	67,244.83	37,140.85	17,537.18	2853.09	31.03	10.13	20.88	8.86	0.28	0.09	0.91	0.19	21,800.18	6952.1	2366.35	1107.1	0.37	0.14
CELGENE CORP	6990.07	9533.46	516.41	828.02	−102.17	255.33	8.94	6.97	0.41	0.37	1.01	0.61	1205.05	1739.36	291.33	644.98	0.7	0.58
CEPHALON INC	3068.23	1707.54	892.42	812.06	−19	36.97	11.77	6.69	0.36	0.27	1.17	0.59	1991.28	1480.49	250.12	212.29	0.39	0.42
CHUGAI PHARMA-CEUTICAL CO LTD	5539.69	3842.74	2205.45	861.26	8.61	2.84	9.71	3.84	0.06	0.06	0.43	0.22	3370.38	1028.68	366.08	110.81	0.52	0.18
CSL LTD	7900.94	6099.15	1708.13	1176.62	15.39	11.11	4.2	2.15	0.1	0.18	0.61	0.19	2717.97	1768.92	108.33	72.32	1.31	0.87
DAIICHI SANKYO COMPANY LTD	11,659.29	4938.3	5849.35	1498.73	6.75	8.57	11.59	5.16	0.12	0.11	0.45	0.16	9108.09	3670.73	811.09	480.41	0.52	0.18
DAINIPPON SUMITOMO PHARMA CO	3378.68	1205.46	2259.99	472.01	6.24	0.78	15.2	2.28	0.03	0.05	0.47	0.13	3410.11	1068.21	356.83	160.75	0.19	0.02
EISAI CO LTD	8028.66	3428.03	3880.81	1851.24	8.2	3.99	12.29	3.77	0.13	0.08	0.52	0.19	5560.26	2798.54	652.87	521.62	0.54	0.21
FOREST LABORATORIES	9474.71	6704.84	1658	1347.78	16.49	8.14	4.12	1.05	0	0	0.41	0.8	2152.57	1579.44	238.25	276.19	0.08	0.03
GENZYME CORP	10,730.88	6312.57	2000.2	1511.98	5.32	5.49	20.71	10.31	0.42	0.28	1.34	0.63	4781.16	3077.57	505.09	414.65	0.25	0.14
GILEAD SCIENCES INC	16,649.45	16,714.45	1785.38	2270.54	4.79	31.7	14.36	8.16	0.31	0.31	0.94	0.4	2734.05	2960.03	495.52	717.71	0.98	1.83
GLAXO SMITHKLINE PHARM LTD	636.32	153.64	288.46	82.49	24.7	6.18	18.46	11.41	0.23	0.1	0.65	0.22	280.17	161.34	1.15	0.35	3.28	7.5
H. LUNDBECK A/S	4760.61	1204.76	1333.61	690.21	21.54	4.03	9.08	3.88	0.16	0.18	0.63	0.48	1579.46	889.68	271.72	155.74	0.37	0.07
HOSPIRA INC	6306.58	1578.22	3252.05	565.35	15.3	4.3	7.4	0.89	0.44	0.53	1.03	0.49	4259.69	1327.2	210.87	58.67	0.19	0.01
JOHNSON & JOHNSON	132,139	56,747.62	36,591.12	16,915.84	26.74	2.45	59.06	32.96	0.83	0.25	2.74	0.71	43,746.71	26,138.13	4259.18	2514.66	0.12	0.1
KYOWA HAKKO KIRIN KOGYO CO	3317.49	1102.35	3295.38	300.29	5.51	2.27	11.24	5.06	0.12	0.13	0.43	0.07	3927.84	1004.95	242.53	56.31	0.65	0.37
LILLY (ELI) & CO	59,326.44	24,894.65	12,061.65	4880.79	24.5	21.01	27.35	11.02	0.28	0.14	0.81	0.2	18,685.02	6196.78	2622.28	1888.32	0.34	0.17
MEDA AB	2321.55	1374.93	969.46	659.53	10.34	4.95	1.83	0.98	0.33	0.82	1.09	1.67	2814.6	1948.14	135.64	118.48	0.53	0.17
MERCK & CO	108,394.8	46,010.48	26,537.43	10,990.2	33.56	9.27	11.29	5.37	0.26	0.21	1.01	0.78	40,876.44	20,851.96	2989.25	1474.63	0.42	0.23
MERCK KGAA	3230.45	2204.51	6812.29	2290.56	16.7	9.1	27.19	5.74	0.36	0.12	1.11	0.24	10,164.58	6331.19	786.44	491.48	0.18	0.05
MITSUBISHI TANABE PHARMA	2731.18	1927.16	1982.22	748.43	4.78	2.29	10.12	3.24	0.15	0.1	0.63	0.25	3134.13	2147.47	256.5	166.74	0.43	0.17

Appendix A (*Continued*)

	Market value		Sales		ROE		Patent H index		CII		EPI		Total assets		R&D expenditures		Citations obtained/patent	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
MYLAN INC	4752.73	1229.25	2300.98	1775.52	4.24	19.27	1.75	0.71	0	0	0.38	0.59	5207.18	4687.23	306.18	458.08	0.34	0.06
NOVARTIS AG	96,950.37	40,660.85	25,615.19	10,163.09	17.37	3.5	38.12	18.3	0.18	0.06	0.74	0.27	47,465.01	22,572.63	3609.47	1959.14	0.31	0.2
NOVO NORDISK A/S	13,807.02	9109.89	4306.27	2484.1	17.74	6.24	14	8.15	0.25	0.12	0.87	0.41	5508.08	2497.45	667.8	444.2	1.03	1.26
PFIZER INC	146,980.5	82,057.34	30,415.08	17,835.86	22.57	11.81	36	18.08	0.24	0.07	0.83	0.15	66,663.69	60,087.36	5294.72	3556.27	0.31	0.19
ROCHE HOLDING AG	103,606.7	33,572.93	23,779.2	11,781.28	20.04	24.62	36.5	17.8	0.37	0.11	1.25	0.33	48,171.77	14,249.12	3821.6	2293.11	0.17	0.09
SANOFI-AVENTIS	55,298.96	45,102.11	15,777.61	15,168.27	12.61	10.43	15.88	7.26	0.21	0.09	0.7	0.2	42,012.69	47,988.85	2825.62	2950.86	0.48	0.2
SHIONOGI & CO LTD	4848.76	2029.5	2780.18	743.29	4.82	1.75	11.94	2.99	0.07	0.08	0.35	0.3	3768.32	544.37	279.14	85.5	0.52	0.22
SHIRE LTD	7074.13	3177.34	1683.55	863.66	−9.54	40.59	9.5	4.6	0.43	0.57	1.07	0.38	4307.65	1192.82	537.94	702.75	0.35	0.41
TAKEDA PHARMA-CEUTICAL CO	35,297.94	15,338.32	9133.29	2637.31	11.84	2.88	25.29	8.72	0.21	0.1	0.74	0.11	17,342.65	7651.54	1226.34	1079.28	0.32	0.15
TEVA PHARMACEU-TICALS	18,600.52	14,487.6	4507.21	4234.92	14.02	5.91	7.27	3.79	0.28	0.26	0.79	0.29	10,261.73	11,647.64	466.07	661.04	0.6	0.29
UCB SA-NV	5895.78	2724.77	2911.19	1155.28	14.71	7.47	7.5	8.64	0.09	0.12	1.43	1.85	6056.67	5179.56	475.32	370.85	0.51	0.55
WATSON PHARMA-CEUTICALS INC	3120.13	1527.99	1166.45	910.03	9.75	10.26	9.53	7.13	0.93	1.32	1.91	1.77	2265.96	1646.24	118.08	146.74	0.11	0.04

Note: The panel data spanned the period of a decade from 1993 to 2009. ‘Mean’ is the average value of the variables from 1997 to 2006, and ‘S.D.’ is the standard deviation of the variables from 1993 to 2009.

References

Bosworth, D. & Rogers, M. (2001). Market value, R&D and intellectual property: An empirical analysis of large Australian firms. *The Economic Record*, *77*(239), 323–337.

Breitzman, A. F., & Narin, F. (2001). 6175824 United States Patent.

Breitzman, A. F., Thomas, P. & Cheney, M. (2002). Technological powerhouse or diluted competence: Techniques for assessing mergers via patent analysis. *R&D Management*, *32*(1), 1–10.

Brown, M. G. & Svenson, R. A. (1998). Measuring R&D productivity. *Research-Technology Management*, *41*(6), 30–35.

Chen, D.-Z., Lin, W.-Y. & Huang, M.-H. (2007). Using essential patent index and essential technological strength to evaluate industrial technological innovation competitiveness. *Scientometrics*, *71*(1), 101–116.

Chen, Y.-S. & Chang, K.-C. (2010). The relationship between a firm's patent quality and its market value – The case of US pharmaceutical industry. *Technological Forecasting and Social Change*, *77*(1), 20–33.

Comanor, W. S. & Scherer, F. M. (1969). Patent statistics as a measure of technical change. *Journal of Political Economy*, *77*, 392–397.

Deng, Z., Lev, B. & Narin, F. (1999). Science and technology as predictors of stock performance. *Financial Analysts Journal*, *55*(3), 20–32.

Greene, W. H. (2003). Simple regression with variable intercepts. In *Econometric analysis*. Upper Saddle River, NJ: Prentice-Hall.

Griliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature*, *28*(4), 1661–1707.

Guan, J. C. & Gao, X. (2009). Exploring the h-index at patent level. *Journal of the American Society for Information Science and Technology*, *60*(1), 35–40.

Hagedoorn, J. & Cloodt, M. (2003). Measuring innovative performance: Is there an advantage in using multiple indicators? *Research Policy*, *32*(8), 1365–1379.

Hall, B. H. (2000). Innovation and market value. In R. Barrell, G. Mason, & M. O. Mahony (Eds.), *Productivity, innovation and economic performance* (pp. 177–198). Cambridge: Cambridge University Press.

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2000). *Market value and patent citations: A first look*. NBER Working Paper, No. 8498.

Hall, B. H., Jaffe, A. & Trajtenberg, M. (2005). Market value and patent citations. *Rand Journal of Economics*, *36*(1), 16–38.

Harhoff, D., Narin, F., Scherer, F. M. & Vopel, K. (1999). Citation frequency and the value of patented inventions. *The Review of Economics and Statistics*, *81*(3), 511–515.

Harhoff, D., Schererc, F. M. & Vopeld, K. (2003). Citations, family size, opposition and the value of patent rights. *Research Policy*, *32*(8), 1343–1363.

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(46), 16569–16572.

Hirschey, M. & Richardson, V. J. (2001). Valuation effects of patent quality: A comparison for Japanese and U.S. firms. *Pacific-Basin Finance Journal*, *9*(1), 65–82.

Hirschey, M., Richardson, V. J. & Scholz, S. (2001). Value relevance of nonfinancial information: The case of patent data. *Review of Quantitative Finance and Accounting*, *17*(3), 223–235.

Hsiao, C. (2003). Models for panel data. In *Analysis of panel data* (2nd ed.). Cambridge University.

Jaffe, A., Trajtenberg, M. & Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics*, *108*(3), 577–598.

Kuan, C.-H., Huang, M.-H. & Chen, D.-Z. (2011). Ranking patent assignee performance by h-index and shape descriptors. *Journal of Informetrics*, *5*(2), 303–312.

Lanjouw, J. O. & Schankerman, M. (2004). Patent quality and research productivity: Measuring innovation with multiple indicators. *The Economic Journal*, *114*(495), 441–465.

Maddala, G. S. (1993). Variance component models. In *The econometrics of panel data*. Edward Elgar Pub.

Narin, F. (1994). Patent bibliometrics. *Scientometrics*, *30*(1), 147–155.

Narin, F., Hamilton, K. S. & Olivastro, D. (1997). The increasing linkage between U.S. technology and public science. *Research Policy*, *26*(3), 317–330.

Narin, F., Noma, E. & Perry, R. (1987). Patents as indicators of corporate technological strength. *Research Policy*, *16*(2-4), 143–155.

Park, G. & Park, Y. (2006). On the measurement of patent stock as knowledge indicators. *Technological Forecasting and Social Change*, *73*(7), 793–812.

Schankerman, M. & Pakes, A. (1986). Estimates of the value of patent rights in european countries during the post-1950 period. *The Economic Journal*, *96*(384), 1052–1076.

Scherer, F. M. (1965). Corporate inventive output, profits, and growth. *Journal of Political Economy*, *73*(2), 190–197.

Shane, H. & Klock, M. (1997). The relation between patent citations and Tobin's Q in the semiconductor industry. *Review of Quantitative Finance and Accounting*, *9*(2), 131–146.

Stolpe, M. (2002). Determinants of knowledge diffusion as evidenced in patent data: The case of liquid crystal display technology. *Research Policy*, *31*(7), 1181–1198.

Stuart, T. E. & Podolny, J. M. (1996). Local search and the evolution of technological capabilities. *Strategic Management Journal*, *17*(special issue), 21–38.

Thomas, P. (2001). A relationship between technology indicators and stock market performance. *Scientometrics*, *51*(1), 319–333.

Trajtenberg, M. (1990). A penny for your quotes: Patent citations and the value of innovations. *Journal of Economics*, *21*(1), 172–187.