國立臺灣大學工學院工業工程學研究所

碩士論文

Graduate Institute of Industrial Engineering

College of Engineering

National Taiwan University

Master Thesis

專利資料分散性與被引用之分佈探究

On the Scattering Distributions of Patent Citation

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中華民國 97 年 1 月

January, 2008

國立臺灣大學
工業工程學研究所

碩士學位論文

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中華民國九十七年一月

致謝

或許，我們常說道：「有一得，必有一失」。那麼，如果說我目前所得到的是人人所稱羨的學位，達到的是人生中該視為有價值的里程碑，對我來說，那或許失去的是在這求學旅程中無法兼顧的友情。對於這些不斷陪伴著、不曾遺棄我的朋友們，我要先說聲感謝。

回眸台大求學研究的路途，像是在漫漫森林中摸索出一條生路，以求達到那另一頭的山巔之處。然而，心中的藍圖清晰可見，往往力行時又似乎伸手而不可及，一個不注意卻又容易在歧途中打轉，此刻回想起來只能說是滿心驚恐與感恩。首先感謝陳達仁老師在我陷入歧途之時，像太陽一般指引著正確的方位，雖說沿途峰迴路轉，至山窮水盡疑無路之時，在您的指導之下總是能夠發現柳暗花明的那一村，這讓我真正體驗到第一學府的研究精神—不懈與精進！另外，也感謝在旅途陷入黑夜膠著中，即時出現的兩盞明燈—黃慕萱老師和林正平老師。感謝黃老師在圖書資訊領域的相關指導，您溫柔與和藹的氣質也是鼓勵我的一個動力；而林老師總是像我們的課後輔導老師，永遠是那樣認真與耐心地提供我們許多研究建議。而在同袍中，第一感謝的當然一起共禦外敵，相互砥礪兩年之久的正宇，還要謝謝你常常叫我起床還忍受我愛遲到的毛病。第二感謝的是程式達人－邱排，雖然你看起來大我兩三歲，但要不是論文封面有格式限制我早就把你放在友情客串了！研究室的好伙伴：又菁、博揚、凱安、雞雞怡，阿宅、游小游、軍師馬爺、和電梯之王喜德龍，我永遠都不會忘記這段友誼。

感謝所辦之：MO 媽、淑云、琍文、相怡四大美女，還有一路相陪的工工所每一位學長姊及學弟妹，無論在生活與課業都給予相當的鼓勵與幫助，這一段也更豐富了我在台大的美好記憶。

最後，也特別感謝我的女友林小妤，不僅完整了我最後的求學生涯，也填補了那塊心靈最重要的缺，這也是讓我堅持到最後一刻的力量。

黃國瑞　2008/01　於台灣大學 IAID 實驗室

摘要

本研究目的乃在於設定一個專利分類準則，用以辨別專利的重要性與價值。其中，書目計量學(Bibliometrics)之布萊德福法則(Bradford’s Law)提供了一個實證方法，本研究得以藉此法則探索此種分類法則，同時亦發現在專利被引用(forward citation)資料中，存在了一個不均勻分佈(unequal distribution)。此外，藉由三個產業的實證研究當中，也發現了專利被引用資料的分佈中存在葛羅斯偏垂(Groos droop)現象，如同書目計量研究，說明了專利被引用中亦有大量專利鮮少被引用的狀況。

專利資料的分散現象在本研究中，藉由圖形發展來探究其成長現象。更進一步地，藉由計量性的探討，基於布萊德福法則下將各產業專利資料分區，並在各產業中進行比較，發現本研究之三個產業專利被引用分佈，具有相同的成長分佈。

最後，本研究亦提出相關的管理意涵，建議公司應專注於自身落在專利分區的第一區專利技術，因其具有相對的發展價值。而建議未來研究方向，則應該專注於這些較具有價值性的專利資料。此外，後續相關於專利之研究變數，也建議參考本研究之專利價值分類準則。而布萊德福法則亦可作為專利資料的整體技術管理方法。

關鍵字：書目計量學、布萊德福法則、專利被引用、不均勻分佈、葛羅斯偏垂

Abstract

The objective of this research is to set up a criterion for classifying the patents by their importance and value. Bradford's law provided a practical method for us to find this criterion and verified the unequal distribution of patent data related to forward citation. Groos droop was also verified which presented in the industries studies that revealed there would be a rule of higher number of patents containing fewer forward citations.

The meaning of patent data scattering was also deeply elaborated and illustrated in some growing patterns. Based on more numerical discussion, it was more precisely depicted that how the distributions in several zones of patent data grew which Bradford was mentioned in the industrial studies. Meanwhile, the comparative discussions on the patent data distributions of three industries were also verified that there would be the similar trends among them.

The managerial implication was discussed in the study as well. It was emphasized that a firm should have more of the patent belonged to the first zone and make effort to focus on the development of the relative technology. The future works were supposed that using the valuable patents, the first zone's patents, was more meaningful than the numerical count of all the patents. Therefore, the other studies about the prediction of firm's performance could modify the independent variable according the criterion made from Bradford. Besides, taking the entire firm's granted patents as a Bradford curve to see the overall development pattern was also a technological development method.

Keywords: Bibliometrics, Bradford's Law, forward citation, unequal distribution, Groos droop

Contents

List of Figures

List of Tables

Chapter 1 Introduction

1.1 Research Background

"Knowledge-based economy" was referred to be the combination of information and knowledge, of which "information" means those data which could be read and understood while "knowledge" indicated the accumulation of messages, techniques, and experience done by using knowledge. From the "Organization for Economic Cooperation and Development (OECD)", "knowledge-based economy" was also referred to be "an economy with the most important output factor which is to own, allocate, produce, and use knowledge resource." The core knowledge, which contributed most to the competency, was often taken as invisible intellectual property such as technological knowledge. Furthermore, "patent" was used to protect their core technological knowledge by most firms all around the world. Patent is a kind of property right of assignee granted by the government for protecting and developing their invention and competitiveness. Moreover, there is a strong relation between patent and invention, which means with more patents, comes more ability of invention. Therefore, it is very critical that technology-based organizations can make more competencies by applying for a patent approval in their industries.

For a technology-based organization, continually technology progressing and changing leads to not only disruptions in the industry, but more uncertainties to this organization as well. So an executive manager has to face the change, understand what the most important and related patent information is, and then making timely and right decisions (Kayal & Water, 1999). Additionally, from the definition of European Patent Office, "patent information" is usually considered as the information of technique, market, law, and all other information relates to its own company from patent office publications. Based on the World Intellectual Property Organization (WIPO) report, patent information is the only document among those technical development data, such as journals, magazines, and encyclopedia that can fully disclose the core technique. Nowadays, it could be observed that patent specifications contained about 90 to 95 percent of the research and development (R&D) results all over the world, however, 80 percent of them were not yet recorded in other publications. From WIPO investigation, R&D time could be shortened up to 60 percent by using patent information effectively, and consequently the cost in R&D could be cut up to 40 percent. Especially, patent data is the information, which was most frequently used by R&D staffs. Not only could this stimulate new research directions, but promote new usage of present techniques and predict industrial growth as well.

Recently, patent-based technology indicators have been developed to the elaboration on measuring the technical strengths of firms, industries and countries. Griliches (1984) was the first person trying to analyze patent data and considering the numbers of granted patents as R&D performance. Also, Griliches (1990) pointed out that using patent information could be the most useful indicator. Choung (1998) also used the patent data to recognize the different technological progress between Taiwan and Korea, then comparing their competitiveness.

Meanwhile, researchers started to focus on and to analyze patent data then tried to find some beneficial information. CHI research, Inc., a consulting company had already developed some considerable technical indicators based on patent citation. The patent citation indicators developed so far were included as follows:

- Current Impact Index (CII): CII shows the citation rate of patents in the last five years being cited during the most current period. CII means the owner of the target patents has more competitiveness when CII is greater than 1.0. Breitzman and Narin (2001) also proposed that a higher citation rate of the patent revealed that the patent was more significant with a higher technological impact.

- Science Linkage (SL): SL shows the number of reference per patent to other scientific publications. The owner of those patents cited a large number of scientific papers possibly appear to work closely with the latest scientific development.

- Technology Cycle Time (TCT): TCT presents "the median age in years of prior patents cited, which provides an indicator of the pace of technological change". Narin (1993) found that different technological industry had different TCT value and demonstrated "in a fast changing area such as electronics, the cycle time may be as fast as three to five years, whereas in some of the very old technologies such as ship and boat building, the cycle time may be in the 15 to 20 year range. Deng *et al*., (1999) thought TCT indicator was the "backward looking and industry dependent" indicator, that is, it took advantage of cited patents from a given patent to calculate the given patent's TCT value, and the value from different industries represent unlike value.

We can identify characteristics in a group of patents to measure patent quality by seeing patent citation. It can also establish linkages between patent documents. Patent citation was also recognized as the technology flow or change and R&D spillover. One patent cited another patent means the knowledge or technology contained in a patent was transited to the other patent. Jaff *et al*., (1992) conducted a research of the extent to which knowledge spillovers were geographically localized by comparing the geographic location of patent citations to those of the cited patents.

Furthermore, researchers also take advantage of patent citation to analyze corporate competitiveness, technology life cycle, competitor analysis, and predict industrial growth. Tomas *et al.*, (2001) also used TCT indicator and other technological indicators as a patent portfolio to measure and predict future stock market performance of a company, and finally they found this investment model did better than the Standard and Poor's (S&P) 500 indexes. Moreover, Pouris (2005) conducted a study to detect the performance of transport research in South Africa and finally observed that research performance of South Africa was relatively well when comparing with other Africa countries, but did very weak comparing with other countries, like Great Britain, Australia, and South Korea and so on. Three main usages in patent citations were proposed by Gay and Le Bas in 2005: (1) Patent citations were used as a measurement of the value of technological inventions; (2) Patent citations were used as a measurement of the origins or the "knowledge base" of inventions; and (3) Patent citations were used as an evaluation of technological knowledge flows.

In recent years, the number of issued patents is growing rapidly, but some of them are useful and valuable while others are not. Valuable patents that contain crucial technology can often help firms to produce more research outcomes and result in more profit to the entire organization. However, less valuable patents have no practical usage and would be disregarded quickly. Therefore, if a criterion could be set up for helping sieving out what valuable patents are, then furthermore we can just spend time to focus on analyzing those useful patents for the future development of new technologies and save more resource. It would be a great contribution to many researchers in carrying out patent analysis. Therefore, it's very useful to find the criterion of recognizing the important and valuable patents.

1.2 Research Motivation and Objectives

In the Bibliometrics, Bradford (1934) revealed the phenomenon of some science journals containing many articles relative to the corresponding specific subject, but other journals were not. He supposed that not every library could afford the great cost to have many of the journals, but it could be more economically for a library just to store the valuable journals which contained the considerable articles. He started his research upon this background and tried to build up a criterion to classify some journals which were valuable and considerable in order to apply to the management in library. Then the unequal distribution was clearly analyzed by other researchers and gradually became a strict principle. Consequently, it was truly a justifiable theory with influence.

Nonetheless, this phenomenon of unequal scattering reappeared in the distribution of patent citation. For several reasons, there were some patents frequently cited by many other patents, but some were not and even never been cited. Thus, there would be a motivation about how the performance and distribution of patent citation were. Especially, by using Bradford's law might be more easily, logically and precisely to find out these phenomena of unequal distribution and to come up with an explicit criterion which could define the valuable and considerable patents, of which we assume the patent was cited frequently, meant it had a very important and future influence to the specific technology. Therefore Bradford's law also might be firstly depicted and verified in the patent field, it would be a significant research contribution to the study of relationship between bibliometrics and patent fields, and it might be more economically in the management of patents.

At the same time, it was also assumed that there would be a “multiplier relation” among the three zones’ number of patents in Bradford’s research. However, it was supposed that there would be a stable proportional relation among the three-zone results in the study. Furthermore, it was assumed that the stable proportional relations would be changed and had different proportional results when the more zones were elaborated, as the three zones might not be the “perfect” separation. Thus, it was firstly deeply discussed the unequal distribution of patent data into three, four, and five zones in terms of “multiplier” and “proportion” relations.

In addition, the comparative discussion about how the different industries’ data distributions would be is also studied in the following sections.

Chapter 2 Determination of the Citation Indicator

2.1 Backward Citation Indicator - A Backward View

Analysis of citations to prior patents on the targeted patent is called “backward citation”. Ashton & Sen (1988) pointed out that *“citations to a previous patent represent evidence that current state-of-the-art developments are related to or were derived from the earlier inventions”*. Backward citation analysis is based on the “indirect information” characteristics, that is, we measure the target patent by the term of its backward citation. But this could only reflect the “passed performance” of those patent owners (firms, industries, or countries) but not their future influence trend. In the other words, backward citation indicator belongs to the “static information” because the value of a fixed year’s data would not be update. Kayal and Water (1999) conducted an empirical evaluation by using TCT indicator to analyze the patent data of superconductor industry from 1974 to 1994, and tried to prove the validity of TCT. The obstacle was that we could not use TCT to predict the future performance of superconductor industry future performance. There would be a bias that we use the backward citation indicator to depict what the patent will perform. However, what we really care is the patents’ future performance and impact to the technology environment.

2.2 Forward Citation Indicator - A Forward View

Analysis of citations on the targeted patent by subsequent patents is called “forward citation”. Forward citation analysis is based on the “direct information” characteristics, that is, we measure the target patent by the term of its forward citation. In fact, forward citation indicator belongs to the “dynamic information” because the value of a fixed year's data would be updated constantly year by year. It is valuable to find out patent's attribute by means of evaluating citations per patent, which was cited by others (forward citation). The assumption was that patent been cited frequently meant it was worthy to be referred and had future influence to the specific technology in terms of the concept of spillover. A patent with higher number of forward citations could be regard as having higher impact to the corresponding technology and industry. Thus, results from patent citation analysis are important for forecasting future technology development, and that means the trends of market development can be accurately evaluated by patent information. Trajtenberg (1989) considered that the intensity of forward citations to a group of patents in subsequent patents had highly relation with the social gains from the target patents. Hall *et al.*, (1998) considered an event that the intensity of forward citations of firm's patents was contemporaneously had highly relation with their performance of market values. Moreover, Hall and Trajtenberg (2004) elaborated on the generality and impact of patents through the concept of probability in patent citation. Haupt *et al.*, (2007) also conducted a research containing the method of forward citation to analyze the technology life cycle stages development.

2.3 Bradford's Law and Groos Droop

Recently, the research on literatures in library and information science had led to a large number of bibliometrics studies. Bradford (1934) found the distribution of literature was the objective phenomenon. Especially, it was common that the science literatures scattered in many different fields, not just in the technological field. Bradford found that some journals with a same specific subject would contain many articles of which were less related to the specific subject, while some journals contained fewer articles of which were in fact highly related to the specific subject. Therefore, Bradford assumed that there might be a scattering principle so that it could be helpful for finding the pattern of scattering. Therefore, Bradford also proposed the “principle of the unity of science” to reflect the relation between articles and their references. Besides, Bradford considered that the articles in each bibliography could be divided into three zones, and each zone included an approximately equal number of articles to each other, while the number of journals required producing those articles increased dramatically from one zone to the next.

First, Bradford collected the data of journals with articles from the bibliography on applied geophysics and lubrication. And he depicted the scattering pattern with vertical axis (R (n)) showing the cumulative number of articles and with the horizontal axis (n) showing the cumulative number of journals. We could find that there would be a quite small portion of journals for a large portion of the cumulative number of articles from the origin, and additional journals outside the core contribution relatively few additional articles. The conceptual scatter was illustrated as shown in figure 2.1.

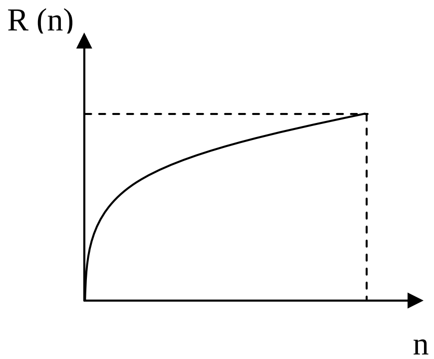

Figure 2.1 The Scattering Pattern of Journals with Articles

Secondly, Bradford found that there would be a linearity relation between “the cumulative number of articles related to the specific object” and “the log value of the cumulative number of journals” in the given object. He then proposed the “law of scattering" and depicted the scattering pattern with the vertical axis(R (n)) showing the cumulative number of articles, and the horizontal axis (Log (n)) showing the logarithm value of the cumulative number of journals.

If scientific journals are arranged in the order of descending number of containing articles for a given subject, they may be divided into a nucleus of journals more particularly devote to the specific subject. Simultaneously, the three zones contain nearly the same number of articles as the nucleus. Then the number of journals ($R_{i,}$ i=1, 2, 3) in the first zone and succeeding zones will be as R_1:R_2:R_3=C (1: r: r^2). We denote that "C" is a constant and "r" is the "multiplier".

The three zones and their characteristics were described as below and shown as in figure 2.2:

1. First zone (AB):

The number of journals (R_1) is the fewest, but it contains the largest number of articles in average, which are related to the specific subject of journals.

2. Second zone (BC)

The number of journals (R2) is fewer, but it contains the larger number of articles in average, which are related to the specific subject of journals.

3. Third zone (CD)

The number of journals (R_3) is the highest, but it contains the fewest number of articles in average, which are related to the specific subject of journals.

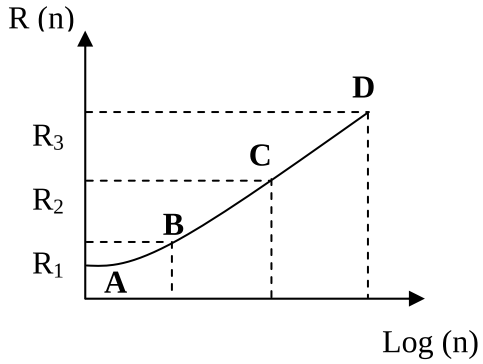

Figure 2.2 The Original Bradford Curve with Three Zones

In 1948, Vickery first concluded the research of “Bradford’s law of scattering” and named Bradford’s principle as “Bradford’s law” formally. Kendall (1960) and Lawani (1973) also conducted a series of researches to prove the evidence of “Bradford’s law” so that Bradford’s discovery could be confirmed and being valuable in the bibliometrics studies. Especially, Leimkuhler (1967) revealed a mathematics research to the “Bradford’s law” and confirmed the law by the descriptions of discussion about three zones. On the other hand, Brookes (1973) also revealed the numerical methods of Bradford’s law and tried to predict the total number of articles by the slope of straight line in the second zone of scattering pattern.

Bradford’s law was successively corrected and proven by many researchers after being proposed. Vickery (1948) revealed the validity of linear view of Bradford. Groos proposed also, “Groos droop” in 1967. He depicted the scattering from Bradford’s law and then found that the line of the third zone might not be linear. On the contrary, there would be “an inflection point” that made the pattern shape became “S” shaped. Moreover, Groos precisely depicted the growth relation as the following description and figure 2.3:

1. First zone (AB): The exponential growth leads to a convex curve which has the increasing progressively positive slope.
2. Second zone (BC): The straight linear growth leads to a line with positive slope.
3. Third zone (CD’): The inverse growth leads to a curve which has “an inflection point” so that the positive slope starts decreasing progressively finally and grew as curve CD’, not as curve CD.

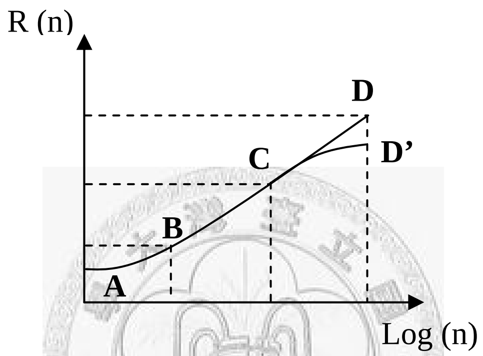

Figure 2.3 Bradford Curve with Groos Droop

After Groos’ correction being proposed, Pope (1975) also conducted statistical analysis and then verified the phenomenon of Groos droop, consequently, “standard Bradford’s law” was proposed, too.

2.4 Industrial Definition

In this study, the “specific technology” was focused for building up a formal research upon the “specific subject” in Bibliometrics. It could be generated as a study by using “industry technology” to represent the “specific technology” and then compile all the relative patent data from our industrial definition. Additionally, this study focused on the granted patents all dating from 1986 to 2006.

The LD industry referenced the industrial definition from the research of discussing the knowledge diffusion in 2002, which conducted by Stolpe. He took the "LCD industry" as his target researching case and defined "LCD industry" for his research containing all the patents in USPTO class 349, "Liquid crystal cells, elements and systems" in this study. Although Stolpe took the USPTO class 349 as the LCD industry, we took a look at the USPTO class definition and knew the class 349 should be regarded as "LD industry" (since the class 349 didn't contain the "crystal technology"). The LD industry covered 13,930 granted patents and only 10,550 patents have forward citations, and the total frequency of forward citation was 130,319 (times). Therefore this study focuses on the patents, which have forward citation, that is, other patents cite them. The highest number of forward citation of patent is 275 times for only one patent, and 1,476 patens have the lowest number of forward citation, that is, 1 time.

Drug industry has been regarded as highly related to biotechnology industry which has been highly emphasized and discussed lately. We took the definition of drug industry revealed by Hall *et al*., (2001) and Lichtenberg and Virabhak (2002) who chose all the patents in USPTO class 424 and 514 which are both entitled "Drug, bio-affecting and body treating compositions" as the scope of drug industry. In the drug industry, it covered 136,700 granted patents and only 75,702 patents were cited, and the total frequency of forward citations was 632,457(times). Compiling the effective 75,702 patents, the highest number of forward citation of patent is 319 times for only one patent, and 16,504 patens have the lowest number of forward citation, that is, 1 time.

Semiconductor industry was the large industry and has been highly developed around the world. The scale and scope of semiconductor industry is large and wide, and the applications of semiconductor have been widely scattered to other industries. Weinstein and Huang (1999) conducted a research about patent analysis in 1999 and define the semiconductor industry by the patent data of USPTO class 257, 365, and 437 as semiconductor patents. In this research, the class 437 was found that the number of patent was abated and combined into class 438 which is entitled "Semiconductor device manufacturing: process," so that 437 was replaced by 438 to the definition of semiconductor industry. Hall *et al.*, (2001) also compiled over 400 USPTO classes into 36 subclasses and further aggregated into 6 main categories. In the research, they classified class 257, 326, 438, and 505 as "Semiconductor Devices" patents. Therefore, by referencing the researches done by Weinstein and Huang (1999) and Hall et al. (2001), the scope of semiconductor industry in this study will be all the patents included in USPTO class 257 entitled "Active solid-state devices (e.g., transistors, solid-state diodes)," 326 entitled "Electronic digital logic circuitry," 438 entitled "Semiconductor device manufacturing: process," and 505 entitled "Superconductor technology: apparatus, material, process." The semiconductor industry covered 202,985 granted patents that contained 153,569 patents were cited, and the total frequency of forward citations was 1,856,999 (times). Compiling the effective 153,569 patents, the highest number of forward citation of patent is 571 times for only two patents, respectively, and 23,469 patens have the lowest number of forward citation, that is, 1 time. The number of granted patents and the relative forward citation in the three industries were cumulated in order and were listed in table 2.1(a), table 2.1(b), and table 2.1(c), respectively.

Table 2.1(a) The Data of LD Industry

Patents	Citations	Cumulative patents	Cumulative citations	log(Cumulative patents)
1	275	1	275	0.0000
1	231	2	506	0.3010
1	203	3	709	0.4771
1	177	4	886	0.6021
1	168	5	1054	0.6990

1	161	6	1215	0.7782
1	156	7	1371	0.8451
2	153	9	1677	0.9542
1	152	10	1829	1.0000
1	151	11	1980	1.0414
1	148	12	2128	1.0792
1	146	13	2274	1.1139
1	142	14	2416	1.1461
2	141	16	2698	1.2041
1	139	17	2837	1.2304
3	137	20	3248	1.3010
1	136	21	3384	1.3222
2	135	23	3654	1.3617
2	134	25	3922	1.3979
1	132	26	4054	1.4150
2	131	28	4316	1.4472
1	130	29	4446	1.4624
1	129	30	4575	1.4771
1	126	31	4701	1.4914
1	125	32	4826	1.5051
1	122	33	4948	1.5185
2	120	35	5188	1.5441
1	119	36	5307	1.5563
1	117	37	5424	1.5682
3	116	40	5772	1.6021
1	114	41	5886	1.6128
1	112	42	5998	1.6232
2	111	44	6220	1.6435
1	110	45	6330	1.6532
2	108	47	6546	1.6721
1	107	48	6653	1.6812
2	106	50	6865	1.6990
1	105	51	6970	1.7076
2	104	53	7178	1.7243
1	103	54	7281	1.7324
4	102	58	7689	1.7634
2	101	60	7891	1.7782
2	100	62	8091	1.7924
3	99	65	8388	1.8129
3	98	68	8682	1.8325

1	97	69	8779	1.8388
5	96	74	9259	1.8692
2	95	76	9449	1.8808
6	94	82	10013	1.9138
1	93	83	10106	1.9191
2	92	85	10290	1.9294
1	91	86	10381	1.9345
3	90	89	10651	1.9494
3	89	92	10918	1.9638
1	88	93	11006	1.9685
1	87	94	11093	1.9731
4	86	98	11437	1.9912
1	85	99	11522	1.9956
2	84	101	11690	2.0043
3	83	104	11939	2.0170
5	82	109	12349	2.0374
2	81	111	12511	2.0453
2	80	113	12671	2.0531
3	79	116	12908	2.0645
4	78	120	13220	2.0792
9	77	129	13913	2.1106
7	76	136	14445	2.1335
7	75	143	14970	2.1553
8	74	151	15562	2.1790
4	73	155	15854	2.1903
11	72	166	16646	2.2201
5	71	171	17001	2.2330
7	70	178	17491	2.2504
6	69	184	17905	2.2648
8	68	192	18449	2.2833
11	67	203	19186	2.3075
9	66	212	19780	2.3263
4	65	216	20040	2.3345
9	64	225	20616	2.3522
9	63	234	21183	2.3692
10	62	244	21803	2.3874
8	61	252	22291	2.4014
9	60	261	22831	2.4166
9	59	270	23362	2.4314
20	58	290	24522	2.4624

12	57	302	25206	2.4800
13	56	315	25934	2.4983
17	55	332	26869	2.5211
15	54	347	27679	2.5403
18	53	365	28633	2.5623
28	52	393	30089	2.5944
12	51	405	30701	2.6075
12	50	417	31301	2.6201
21	49	438	32330	2.6415
16	48	454	33098	2.6571
18	47	472	33944	2.6739
22	46	494	34956	2.6937
23	45	517	35991	2.7135
24	44	541	37047	2.7332
21	43	562	37950	2.7497
23	42	585	38916	2.7672
29	41	614	40105	2.7882
26	40	640	41145	2.8062
42	39	682	42783	2.8338
32	38	714	43999	2.8537
31	37	745	45146	2.8722
41	36	786	46622	2.8954
46	35	832	48232	2.9201
44	34	876	49728	2.9425
39	33	915	51015	2.9614
39	32	954	52263	2.9795
52	31	1006	53875	3.0026
53	30	1059	55465	3.0249
64	29	1123	57321	3.0504
57	28	1180	58917	3.0719
63	27	1243	60618	3.0945
64	26	1307	62282	3.1163
99	25	1406	64757	3.1480
80	24	1486	66677	3.1720
93	23	1579	68816	3.1984
111	22	1690	71258	3.2279
125	21	1815	73883	3.2589
125	20	1940	76383	3.2878
127	19	2067	78796	3.3153
130	18	2197	81136	3.3418

159	17	2356	83839	3.3722
177	16	2533	86671	3.4036
209	15	2742	89806	3.4381
173	14	2915	92228	3.4646
248	13	3163	95452	3.5001
256	12	3419	98524	3.5339
306	11	3725	101890	3.5711
332	10	4057	105210	3.6082
357	9	4414	108423	3.6448
431	8	4845	111871	3.6853
484	7	5329	115259	3.7266
499	6	5828	118253	3.7655
623	5	6451	121368	3.8096
687	4	7138	124116	3.8536
855	3	7993	126681	3.9027
1081	2	9074	128843	3.9578
1476	1	10550	130319	4.0233

Table 2.1(b) The Data of Drug Industry

Patents	Citations	Cumulative patents	Cumulative citations	log(Cumulative patents)
1	319	1	319	0.0000
1	268	2	587	0.3010
1	264	3	851	0.4771
1	235	4	1086	0.6021
1	226	5	1312	0.6990
1	219	6	1531	0.7782
1	218	7	1749	0.8451
1	216	8	1965	0.9031
1	209	9	2174	0.9542
1	207	10	2381	1.0000
1	202	11	2583	1.0414
1	201	12	2784	1.0792
1	195	13	2979	1.1139
1	194	14	3173	1.1461
1	193	15	3366	1.1761
2	192	17	3750	1.2304
1	189	18	3939	1.2553
1	186	19	4125	1.2788
1	185	20	4310	1.3010

1	184	21	4494	1.3222
1	182	22	4676	1.3424
1	180	23	4856	1.3617
1	178	24	5034	1.3802
1	177	25	5211	1.3979
1	175	26	5386	1.4150
1	174	27	5560	1.4314
1	173	28	5733	1.4472
1	172	29	5905	1.4624
1	170	30	6075	1.4771
1	169	31	6244	1.4914
1	168	32	6412	1.5051
1	165	33	6577	1.5185
1	164	34	6741	1.5315
1	163	35	6904	1.5441
2	161	37	7226	1.5682
1	160	38	7386	1.5798
1	158	39	7544	1.5911
1	157	40	7701	1.6021
2	156	42	8013	1.6232
1	155	43	8168	1.6335
2	153	45	8474	1.6532
1	152	46	8626	1.6628
1	151	47	8777	1.6721
1	150	48	8927	1.6812
2	149	50	9225	1.6990
2	148	52	9521	1.7160
2	147	54	9815	1.7324
4	146	58	10399	1.7634
4	145	62	10979	1.7924
3	144	65	11411	1.8129
3	143	68	11840	1.8325
2	142	70	12124	1.8451
2	141	72	12406	1.8573
3	140	75	12826	1.8751
2	138	77	13102	1.8865
1	136	78	13238	1.8921
3	135	81	13643	1.9085
1	134	82	13777	1.9138
2	133	84	14043	1.9243

4	132	88	14571	1.9445
1	131	89	14702	1.9494
2	130	91	14962	1.9590
4	128	95	15474	1.9777
3	127	98	15855	1.9912
6	126	104	16611	2.0170
4	125	108	17111	2.0334
10	123	118	18341	2.0719
2	122	120	18585	2.0792
2	121	122	18827	2.0864
7	120	129	19667	2.1106
5	119	134	20262	2.1271
5	118	139	20852	2.1430
7	117	146	21671	2.1644
2	116	148	21903	2.1703
5	115	153	22478	2.1847
5	114	158	23048	2.1987
8	113	166	23952	2.2201
3	112	169	24288	2.2279
1	111	170	24399	2.2304
10	110	180	25499	2.2553
5	109	185	26044	2.2672
4	108	189	26476	2.2765
10	107	199	27546	2.2989
5	106	204	28076	2.3096
5	105	209	28601	2.3201
2	104	211	28809	2.3243
7	103	218	29530	2.3385
4	102	222	29938	2.3464
4	101	226	30342	2.3541
5	100	231	30842	2.3636
8	99	239	31634	2.3784
9	98	248	32516	2.3945
9	97	257	33389	2.4099
6	96	263	33965	2.4200
7	95	270	34630	2.4314
8	94	278	35382	2.4440
9	93	287	36219	2.4579
9	92	296	37047	2.4713
7	91	303	37684	2.4814

10	90	313	38584	2.4955
14	89	327	39830	2.5145
8	88	335	40534	2.5250
14	87	349	41752	2.5428
15	86	364	43042	2.5611
11	85	375	43977	2.5740
14	84	389	45153	2.5899
5	83	394	45568	2.5955
16	82	410	46880	2.6128
16	81	426	48176	2.6294
19	80	445	49696	2.6484
16	79	461	50960	2.6637
19	78	480	52442	2.6812
17	77	497	53751	2.6964
17	76	514	55043	2.7110
32	75	546	57443	2.7372
16	74	562	58627	2.7497
15	73	577	59722	2.7612
18	72	595	61018	2.7745
21	71	616	62509	2.7896
33	70	649	64819	2.8122
24	69	673	66475	2.8280
21	68	694	67903	2.8414
24	67	718	69511	2.8561
30	66	748	71491	2.8739
41	65	789	74156	2.8971
23	64	812	75628	2.9096
33	63	845	77707	2.9269
30	62	875	79567	2.9420
29	61	904	81336	2.9562
32	60	936	83256	2.9713
36	59	972	85380	2.9877
45	58	1017	87990	3.0073
43	57	1060	90441	3.0253
47	56	1107	93073	3.0441
52	55	1159	95933	3.0641
48	54	1207	98525	3.0817
46	53	1253	100963	3.0980
57	52	1310	103927	3.1173
56	51	1366	106783	3.1355

51	50	1417	109333	3.1514
57	49	1474	112126	3.1685
54	48	1528	114718	3.1841
53	47	1581	117209	3.1989
64	46	1645	120153	3.2162
71	45	1716	123348	3.2345
92	44	1808	127396	3.2572
95	43	1903	131481	3.2794
99	42	2002	135639	3.3015
82	41	2084	139001	3.3189
106	40	2190	143241	3.3404
113	39	2303	147648	3.3623
114	38	2417	151980	3.3833
123	37	2540	156531	3.4048
142	36	2682	161643	3.4285
174	35	2856	167733	3.4558
167	34	3023	173411	3.4804
157	33	3180	178592	3.5024
216	32	3396	185504	3.5310
219	31	3615	192293	3.5581
221	30	3836	198923	3.5839
249	29	4085	206144	3.6112
293	28	4378	214348	3.6413
280	27	4658	221908	3.6682
316	26	4974	230124	3.6967
323	25	5297	238199	3.7240
411	24	5708	248063	3.7565
461	23	6169	258666	3.7902
491	22	6660	269468	3.8235
511	21	7171	280199	3.8556
587	20	7758	291939	3.8897
598	19	8356	303301	3.9220
723	18	9079	316315	3.9580
815	17	9894	330170	3.9954
855	16	10749	343850	4.0314
985	15	11734	358625	4.0694
1093	14	12827	373927	4.1081
1195	13	14022	389462	4.1468
1399	12	15421	406250	4.1881
1532	11	16953	423102	4.2292

1833	10	18786	441432	4.2738
2159	9	20945	460863	4.3211
2523	8	23468	481047	4.3705
2996	7	26464	502019	4.4227
3758	6	30222	524567	4.4803
4559	5	34781	547362	4.5413
5994	4	40775	571338	4.6104
7769	3	48544	594645	4.6861
10654	2	59198	615953	4.7723
16504	1	75702	632457	4.8791

Table 2.1(c) The Data of Semiconductor Industry

Patents	**Citations**	**Cumulative patents**	**Cumulative citations**	**log(Cumulative patents)**
2	571	2	1142	0.3010
1	463	3	1605	0.4771
1	415	4	2020	0.6021
1	406	5	2426	0.6990
1	365	6	2791	0.7782
1	364	7	3155	0.8451
1	361	8	3516	0.9031
2	360	10	4236	1.0000
1	358	11	4594	1.0414
2	357	13	5308	1.1139
1	349	14	5657	1.1461
1	346	15	6003	1.1761
1	337	16	6340	1.2041
2	335	18	7010	1.2553
1	334	19	7344	1.2788
1	330	20	7674	1.3010
1	328	21	8002	1.3222
1	318	22	8320	1.3424
2	317	24	8954	1.3802
1	315	25	9269	1.3979
2	309	27	9887	1.4314
1	306	28	10193	1.4472
1	296	29	10489	1.4624
1	292	30	10781	1.4771
2	290	32	11361	1.5051
2	286	34	11933	1.5315

1	285	35	12218	1.5441
2	278	37	12774	1.5682
1	277	38	13051	1.5798
2	275	40	13601	1.6021
1	271	41	13872	1.6128
1	264	42	14136	1.6232
1	262	43	14398	1.6335
2	261	45	14920	1.6532
1	260	46	15180	1.6628
1	258	47	15438	1.6721
2	244	49	15926	1.6902
2	242	51	16410	1.7076
2	239	53	16888	1.7243
3	238	56	17602	1.7482
4	236	60	18546	1.7782
2	235	62	19016	1.7924
2	234	64	19484	1.8062
1	233	65	19717	1.8129
1	231	66	19948	1.8195
1	225	67	20173	1.8261
2	222	69	20617	1.8388
5	221	74	21722	1.8692
1	219	75	21941	1.8751
3	218	78	22595	1.8921
6	217	84	23897	1.9243
1	216	85	24113	1.9294
3	214	88	24755	1.9445
1	213	89	24968	1.9494
2	212	91	25392	1.9590
6	211	97	26658	1.9868
2	210	99	27078	1.9956
1	209	100	27287	2.0000
3	208	103	27911	2.0128
1	205	104	28116	2.0170
3	204	107	28728	2.0294
1	202	108	28930	2.0334
4	201	112	29734	2.0492
2	199	114	30132	2.0569
2	197	116	30526	2.0645
1	196	117	30722	2.0682

1	195	118	30917	2.0719
4	194	122	31693	2.0864
3	193	125	32272	2.0969
4	191	129	33036	2.1106
4	190	133	33796	2.1239
5	189	138	34741	2.1399
2	188	140	35117	2.1461
5	187	145	36052	2.1614
4	186	149	36796	2.1732
4	185	153	37536	2.1847
5	184	158	38456	2.1987
1	183	159	38639	2.2014
2	182	161	39003	2.2068
7	181	168	40270	2.2253
2	180	170	40630	2.2304
2	179	172	40988	2.2355
2	178	174	41344	2.2405
7	177	181	42583	2.2577
2	176	183	42935	2.2625
4	175	187	43635	2.2718
3	174	190	44157	2.2788
1	173	191	44330	2.2810
4	172	195	45018	2.2900
4	171	199	45702	2.2989
3	170	202	46212	2.3054
7	168	209	47388	2.3201
5	167	214	48223	2.3304
5	166	219	49053	2.3404
6	165	225	50043	2.3522
7	163	232	51184	2.3655
2	162	234	51508	2.3692
6	161	240	52474	2.3802
9	160	249	53914	2.3962
1	159	250	54073	2.3979
8	158	258	55337	2.4116
3	157	261	55808	2.4166
14	156	275	57992	2.4393
7	155	282	59077	2.4502
6	154	288	60001	2.4594
7	153	295	61072	2.4698

3	152	298	61528	2.4742
8	151	306	62736	2.4857
10	150	316	64236	2.4997
4	149	320	64832	2.5051
10	148	330	66312	2.5185
3	147	333	66753	2.5224
5	146	338	67483	2.5289
9	145	347	68788	2.5403
10	144	357	70228	2.5527
6	143	363	71086	2.5599
13	142	376	72932	2.5752
5	141	381	73637	2.5809
6	140	387	74477	2.5877
13	139	400	76284	2.6021
7	138	407	77250	2.6096
8	137	415	78346	2.6180
12	136	427	79978	2.6304
9	135	436	81193	2.6395
12	134	448	82801	2.6513
6	133	454	83599	2.6571
17	132	471	85843	2.6730
18	131	489	88201	2.6893
11	130	500	89631	2.6990
19	129	519	92082	2.7152
11	128	530	93490	2.7243
19	127	549	95903	2.7396
11	126	560	97289	2.7482
12	125	572	98789	2.7574
11	124	583	100153	2.7657
6	123	589	100891	2.7701
15	122	604	102721	2.7810
21	121	625	105262	2.7959
22	120	647	107902	2.8109
17	119	664	109925	2.8222
16	118	680	111813	2.8325
13	117	693	113334	2.8407
23	116	716	116002	2.8549
19	115	735	118187	2.8663
26	114	761	121151	2.8814
18	113	779	123185	2.8915

20	112	799	125425	2.9025
14	111	813	126979	2.9101
28	110	841	130059	2.9248
24	109	865	132675	2.9370
17	108	882	134511	2.9455
15	107	897	136116	2.9528
26	106	923	138872	2.9652
23	105	946	141287	2.9759
29	104	975	144303	2.9890
22	103	997	146569	2.9987
29	102	1026	149527	3.0111
25	101	1051	152052	3.0216
29	100	1080	154952	3.0334
22	99	1102	157130	3.0422
32	98	1134	160266	3.0546
43	97	1177	164437	3.0708
32	96	1209	167509	3.0824
42	95	1251	171499	3.0973
19	94	1270	173285	3.1038
39	93	1309	176912	3.1169
46	92	1355	181144	3.1319
25	91	1380	183419	3.1399
53	90	1433	188189	3.1562
45	89	1478	192194	3.1697
45	88	1523	196154	3.1827
45	87	1568	200069	3.1953
53	86	1621	204627	3.2098
45	85	1666	208452	3.2217
48	84	1714	212484	3.2340
67	83	1781	218045	3.2507
47	82	1828	221899	3.2620
72	81	1900	227731	3.2788
62	80	1962	232691	3.2927
66	79	2028	237905	3.3071
39	78	2067	240947	3.3153
85	77	2152	247492	3.3328
63	76	2215	252280	3.3454
81	75	2296	258355	3.3610
82	74	2378	264423	3.3762
62	73	2440	268949	3.3874

77	72	2517	274493	3.4009
91	71	2608	280954	3.4163
103	70	2711	288164	3.4331
131	69	2842	297203	3.4536
105	68	2947	304343	3.4694
120	67	3067	312383	3.4867
92	66	3159	318455	3.4995
121	65	3280	326320	3.5159
139	64	3419	335216	3.5339
129	63	3548	343343	3.5500
142	62	3690	352147	3.5670
125	61	3815	359772	3.5815
120	60	3935	366972	3.5949
146	59	4081	375586	3.6108
157	58	4238	384692	3.6272
167	57	4405	394211	3.6439
174	56	4579	403955	3.6608
165	55	4744	413030	3.6761
184	54	4928	422966	3.6927
201	53	5129	433619	3.7100
203	52	5332	444175	3.7269
191	51	5523	453916	3.7422
251	50	5774	466466	3.7615
292	49	6066	480774	3.7829
277	48	6343	494070	3.8023
258	47	6601	506196	3.8196
275	46	6876	518846	3.8373
295	45	7171	532121	3.8556
309	44	7480	545717	3.8739
299	43	7779	558574	3.8909
363	42	8142	573820	3.9107
377	41	8519	589277	3.9304
422	40	8941	606157	3.9514
450	39	9391	623707	3.9727
461	38	9852	641225	3.9935
466	37	10318	658467	4.0136
488	36	10806	676035	4.0337
557	35	11363	695530	4.0555
621	34	11984	716644	4.0786
633	33	12617	737533	4.1010

568	32	13185	755709	4.1201
720	31	13905	778029	4.1432
739	30	14644	800199	4.1657
820	29	15464	823979	4.1893
823	28	16287	847023	4.2118
991	27	17278	873780	4.2375
1097	26	18375	902302	4.2642
1046	25	19421	928452	4.2883
1238	24	20659	958164	4.3151
1319	23	21978	988501	4.3420
1543	22	23521	1022447	4.3715
1534	21	25055	1054661	4.3989
1742	20	26797	1089501	4.4281
1840	19	28637	1124461	4.4569
2026	18	30663	1160929	4.4866
2206	17	32869	1198431	4.5168
2286	16	35155	1235007	4.5460
2690	15	37845	1275357	4.5780
2888	14	40733	1315789	4.6099
3208	13	43941	1357493	4.6429
3684	12	47625	1401701	4.6778
3969	11	51594	1445360	4.7126
4517	10	56111	1490530	4.7490
5189	9	61300	1537231	4.7875
5814	8	67114	1583743	4.8268
6427	7	73541	1628732	4.8665
7717	6	81258	1675034	4.9099
8888	5	90146	1719474	4.9549
10492	4	100638	1761442	5.0028
13110	3	113748	1800772	5.0559
16379	2	130127	1833530	5.1144
23469	1	153596	1856999	5.1864

Chapter 3 The Unequal Distribution of Patent Data

3.1 The Scattering of Patents Data

Before the discussion of separations, the scattering of patents data was describing first. Then the pattern of the scattering of each industry was drawn with cumulative citations (vertical axis) and cumulative patents (horizontal axis). From the pattern, the observation of how the cumulative of patents and forward citations growth would be is clear. If there would be a phenomenon of which “fewer number of patent containing larger number of forward citation” likes the state of journals from the research in the bibilometric field discussed earlier, that conceptual figure would be shown in figure 3.1. From the origin, the slope of this curve is higher showing the fact that less number of patents reaches higher number of forward citation. To the posterior portion, the slope of this curve is still positive but decreasing slowly tells that there is a large number of patents contain fewer and fewer forward citations. In the discussion, it was also found the unequal distributions in the three industries were the same as Bradford’s studying results. In statistics, it is a disproportionate distribution that exists the different and valuable characteristics to be discussed furthermore.

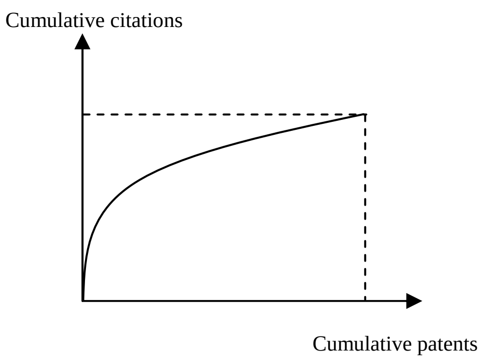

Figure 3.1 The Scattering of Industry

The scattering patterns of three industries were illustrated in figure 3.2(a), figure 3.2(b) and figure 3.2(c) by the patent data in table 2.1(a), table 2.1(b) and table 2.1(c), respectively. There would be a similar pattern in the three industries with a gradually decreasing slope meant a higher number of patents containing fewer forward citations from the origin. To the posterior portion, fewer patents contained higher number of forward citations reflecting there were some outliers existing in the patent data.

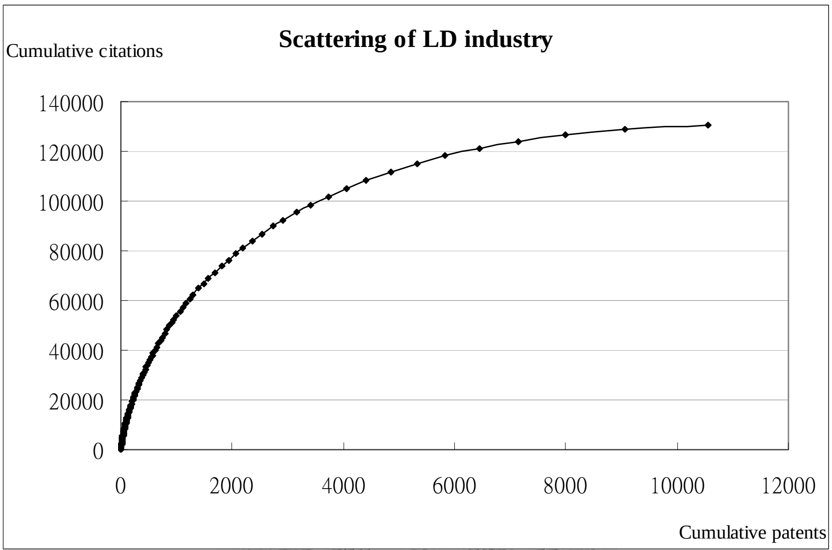

Figure 3.2(a) The Scattering of LD Industry

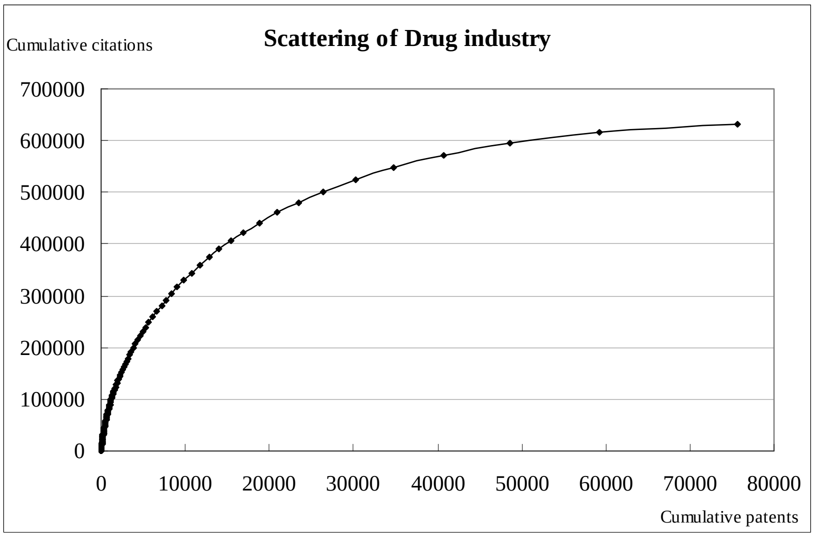

Figure 3.2(b) The Scattering of Drug Industry

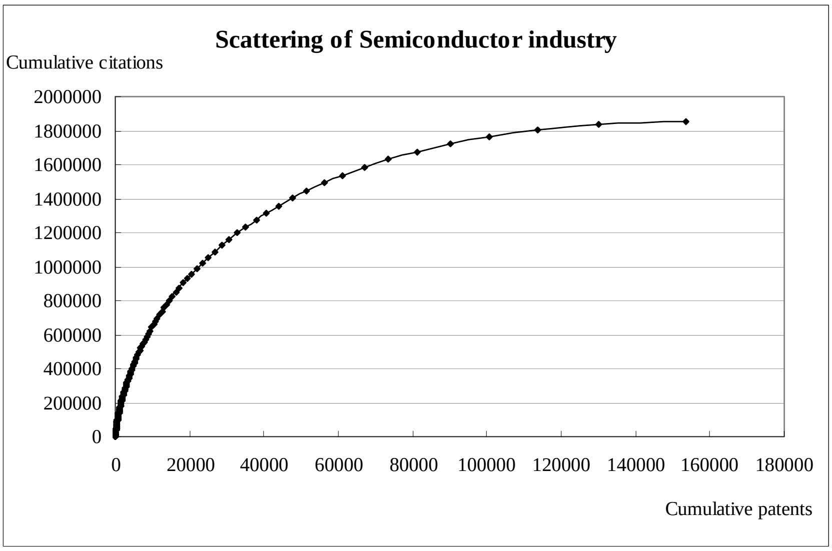

Figure 3.2(c) The Scattering of Semiconductor Industry

3.2 Analysis on Patent Forward Citation Numbers – into Three Zones

It was also tried to use the number of granted patents (which have forward citation) and their forward citations that parallel the science journals and the containing articles according to the Bradford's studying method. Patents are arranged in the order of descending number of forward citation for a given industry so that they would be divided into a zone of patents more particularly devote to the given industry. Simultaneously, computing and sorting out the three zones containing nearly the same number of forward citations as the nucleus. Then the number of patents ($R_{i,}$ i=1, 2, 3) in the first zone and succeeding zones will be as R_1:R_2:R_3=C (1: r: r^2). We denote that "C" is the constant and "r" is the "multiplier" as well. With the multiplier it could be expected the number of granted patents between three zones. And from the grouping method, it could be more easily to be found there was a phenomenon that fewer patents have greater number of forward citations, and a higher number of patents containing fewer forward citations. And the data was compiled in the equal citations as the following tables.

Table 3.1 The Equal Citations into Three Zones

(a) The LD Industry

Zone	Citation times	Number of Patents	Percentage of Patents	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	43999	714	6.77%	714	2.8537	61.62
Second	42672	1819	17.24%	2533	3.4036	23.46
Third	43648	8017	75.99%	10550	4.0233	5.44
Total	130319	10550	100.00%			

*n=cumulative patents

(b) The Drug Industry

Zone	Citation times	Number of Patents	Percentage of Patents	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	214348	4378	5.78%	4378	3.6413	48.96
Second	208754	12575	16.61%	12575	4.2292	16.60
Third	209355	58749	77.61%	58749	4.8791	3.56
Total	632457	75702	100.00%			

*n=cumulative patents

(c) The Semiconductor Industry

Zone	Citation times	Number of Patents	Percentage of Patents	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	623707	9391	6.11%	9391	3.9727	66.42
Second	611300	25764	16.77%	35155	4.5460	23.73
Third	621992	118441	77.11%	153596	5.1864	5.25
Total	1856999	153596	100.00%			

*n=cumulative patents

In LD industry, the three zones are compiled into table 3.1 (a) according to the one third of total forward citations that is nearly equal to 43,440 times. Then the numbers of patents ($R_{i,}$ i=1, 2, 3) in the first zone and succeeding zones are R_1:R_2:R_3=714:1819:8017=714(1:2.55:11.23), of which the constant is C=714. And the multiplier (r) might be general about 3. Furthermore, the average citation ratios of patent to citation are also computed in each zone. The value of average in the first zone is about 61.62, and then reduced to 23.46 in the second zone, and the value in the third zone is about 5.44. This reveals the phenomenon that the patents in the first zone have relative highly impact and value to the LD technology while the patents from the third zone have relative lowest influence to this specific technology. Besides, the patents in the second zone have a relative influence between the other zones.

In the drug industry, the three zones are compiled into table 3.1 (b) by the one third of total forward citations that is nearly equal to 210,819 times. Then the numbers of patents ($R_{i,}$ i=1, 2, 3) in the zones are R_1:R_2:R_3=4,378:12,571:58,749=4,378(1:2.87:13.42), of which the constant is C=4,378. And the multiplier (r) might be general about 3, too. Moreover, the average citation ratios of patent to citation are also computed in each zone. The value in the first zone is about 48.96, and then reduced to 16.60 in the second zone, and the value in the third zone is about 3.56. It also tells the phenomenon that the patents in the first zone have relative highly impact and value to a drug technology, like LD industry, and the patents in the third zone have relative lowest influence to this specific technology. In addition, the patents in the second zone have a relative influence between the two zones.

In the semiconductor industry, the three zones are compiled into table 3.1 (c) according to the one third of total forward citations that is nearly equal to 619,000 times. Then the numbers of patents ($R_{i,}$ i=1, 2, 3) in the zones are R_1:R_2:R_3=9,391:25,764:118,441=9,391(1:2.74:12.61), of which the constant is C=9,391. And the multiplier (r) might be general about 3 also. Besides, the average citation ratios of patent to citation are also computed in each zone. The value in the first zone is about 48.96, and then reduced to 16.60 in the second zone, and the value in the third zone is about 3.56. This reveals the phenomenon also that the patents in the first zone have relative highly impact and value to a drug technology, like LD and drug industry, and the patents from the third zone have relative lowest influence to this technology. In fact, the patents in the second zone have a relative influence between the other zones.

3.3 Analysis on Patent Forward Citation Proportionalities - into Three Zones

Additionally, it was supposed that there should be a proportional conclusion. This would be also easily to expect the number of granted patents by the portions in the three zones. On the other hand, the "marginal productivity" from Economics was also quoted to define that the patent contains more forward citations as a highly marginal productivity patent, which could reveal patent's importance. The percentages of distribution were shown in table 3.1.

From the results, we can more clearly observe the relative distribution of each number. There would be 6% of granted patents in the first; 16% of granted patents in the second; and there would be about 77% of granted patents in the third. All the three zones' patents contained the same percentage of 33% about citations. Thus, there would be a relative highly marginal productivity for the patents in the first zone in terms of economics because it cost relative low number of patents reach the same portion of forward citation. However, the patents in the third zone should be less important since it cost much more patents to reach the same portion of forward citation.

A firm with more patents in first zone means it had more core technologies and competences in the specific technology and would be the leader firm of the industry in R&D development. In the contrary, the patents in the third zone was less valuable and could be viewed as almost not yet be cited as their forward citations were just less then

10 times on average and hard to have certain influence. This state might reveal that these patents had no valuable technology and knowledge for developing the specific technology. A firm had more of these unhelpful patents meant it took too much R&D resource devoting to the unimportant technology. Then it could be set up a criterion that the firms or countries should try to add the value of the patents and make effort to have the first-zone-patents because this meant the firm or country had the great influence in a specific technology if they dominate more of the first zone's patents. It also could be the goal in R&D developing that a firm should reach.

3.4 Analysis on Patent Forward Citation Numbers – into Four Zones

In the section, patents are arranged in the order of descending number of forward citation for a given industry so that they would be divided into a zone of patents more particularly devote to the given industry. Simultaneously, computing and sorting out the four zones containing nearly the same number of forward citations as the nucleus. Then the number of patents ($R_{i,}$ i=1, 2, 3, 4) in the first zone and succeeding zones will be as R_1:R_2:R_3:R_4=C (1: r: r^2: r^3). We denote that "C" is the constant and "r" is the "multiplier" as well. With the multiplier it could be expected the number of granted patents between four zones. And from the grouping method, it could be more easily to be found there was a phenomenon that fewer patents have more number of forward citations, and a higher number of patents containing fewer forward citations. And the data was compiled in the equal citation as the following tables.

Table 3.2 The Equal Citations into Four Zones

(a) The LD Industry

Zone	Citations	Number of Patents	Percentage of Patents	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	32330	438	4.15%	438	2.6415	73.81
Second	32427	968	9.18%	1406	3.1480	33.50
Third	33767	2013	19.08%	3419	3.5339	16.77
Fourth	31795	7131	67.59%	10550	4.0233	4.46
Total	130319	10550	100.00%			

*n=cumulative patents

(b) The Drug Industry

Zone	Citation times	Number of Patents	Percentage of Patents	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	156531	2540	3.36%	2540	3.4048	61.63
Second	159784	6539	8.64%	9079	3.9580	24.44
Third	164732	14389	19.01%	23468	4.3705	11.45
Fourth	151410	52234	69.00%	75702	4.8791	2.90
Total	632457	75702	100.00%			

*n=cumulative patents

(c) The Semiconductor Industry

Zone	Citation times	Number of Patents	Percentage of Patents	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	466466	5774	3.76%	5774	3.7615	80.79
Second	461986	13647	8.88%	19421	4.2883	33.85
Third	473249	28204	18.36%	47625	4.6778	16.78
Fourth	455298	105971	68.99%	153596	5.1864	4.30
Total	1856999	153596	100.00%			

*n=cumulative patents

In LD industry, the four zones are compiled into table 3.2(a) according to the one fourth of total forward citations that is nearly equal to 32,580 times. Then the numbers of patents ($R_{i,}$ i=1, 2, 3, 4) in the first zone and succeeding zones are R_1:R_2:R_3:R_4=438:968:2013:7131=438(1:2.21:4.60:16.28) which the constant is C=438. And the multiplier (r) might not be generally computed. Furthermore, the average citation ratio of patent to citation is also computed in each zone. The value in the first zone is about 73.81, and then reduced to 33.50 in the second zone, and the value in the third zone is about 16.77, then 4.46 in the fourth zone. This reveals the phenomenon that the patents in the first zone have relative highly impact and value to a LD technology, and the patents belonged to the fourth zone have relative lowest influence to this technology. It was more obvious that there would be an unequal data distribution after conducting four zones results (comparing to the-three-zones results).

In the drug industry, the four zones are compiled into table 3.2(b) according to the one fourth of total forward citations that is nearly equal to 158,114 times. Then the numbers of patents ($R_{i,}$ i=1, 2, 3, 4) in the zones are R_1:R_2:R_3:R_4=2,540:6,539:14,389:52,234=2,540 (1:2.57:5.66:20.56) which the constant is C=2,540. And the multiplier (r) might not be generally computed, too. Moreover, the average citation ratio of patent to citation is also computed in each zone. The value in the first zone is about 61.63, and then reduces to 24.44 in the second zone, and the value in the third and fourth zone is about 11.45 and 2.90. This also reveals the phenomenon that the patents in the first zone have relative highly impact and value to a drug technology like LD industry, and the patents in the fourth zone have relative lowest influence to this technology.

In the semiconductor industry, the four zones are compiled into table 3.2(c) according to the one fourth of total forward citations that is nearly equal to 464,250 times. Then the numbers of patents ($R_{i,}$ i=1, 2, 3, 4) in the zones are R_1:R_2:R_3:R_4=5,774:13,647:28,204,105,971=5,774(1:2.36:4.88:18.35) which the constant is C=5,774. And the multiplier (r) might not be generally computed. In fact, the average citation ratio of patent to citation is also computed in each zone. The value in the first zone is about 80.79, and then reduced to 33.85 in the second zone, and the value in the third zone is about 16.78 and 4.30 in the fourth zone. This reveals the phenomenon that the patents in the first zone have relative highly impact and value to a drug technology; such as LD and drug industry, and the patents belonged to the fourth zone have relative lowest influence to this technology.

3.5 Analysis on Patent Forward Citation Proportionalities – into Four Zones

The relative distribution of each number can be more clearly observed by the-fourth-zones results from the table 3.2. There would be 4% of granted patents in first; 9% of granted patents in second; 19% and 68% of granted patents in third and fourth zone, respectively. All the zones' patents contained the same percentage of 25% about citations. Thus, there would be a relative highly marginal productivity for the patents in terms of economics in the first zone because it cost relative low number of patents reach the same portion of forward citation. Besides, the patents in the fourth zone should be less important since it cost much more patents to contain the same portion of forward citation.

A firm had more of these patents in first zone meant it had more core technology in the specific technology and would be the leader firm of the industry in R&D development. In comparison, the patents in the fourth zone was less valuable and could be viewed as almost not yet be cited as the forward citations was just less then 5 times on average in our cases. This state might reveal these patents had no valuable technology and knowledge for the development of the specific technology. A firm had more of these patents meant it took much R&D resource to the development of unimportant technology. Then it could be set up a criterion that the firms or countries should try to add the value of the patents and make effort to have the first-zone-patents because this meant the firm or country had the great influence in a specific technology if they dominate more of the first zone's patents. It also could be the goal in R&D developing that a firm should reach.

3.6 Analysis on Patent Forward Citation Numbers – into Five Zones

In the section, patents are arranged in the order of descending number of forward citation for a given industry so that they would be divided into a zone of patents more particularly devote to the given industry. Simultaneously, computing and sorting out the five zones containing nearly the same number of forward citations as a zone. Then the number of patents ($R_{i,}$ i=1, 2, 3, 4, 5) in the first zone and succeeding zones will be as R_1:R_2:R_3 R_4:R_5=C (1: r: r^2: r^3: r^4). We denote that "C" is the constant and "r" is the "multiplier" as well. With the multiplier it could be expected the number of granted patents between five zones. And it could be more easily to be found there was a phenomenon that fewer patents have more number of forward citations from the grouping method, and a higher number of patents containing fewer forward citations. Thus, the data was compiled in the equal citation as the following tables.

Table.3.3 The Equal Citations into Five Zones

(a) The LD Industry

Zone	Citations	Number of Patent	Percentage of Patent	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	25934	315	2.99%	315	2.4983	82.33
Second	26329	639	6.06%	954	2.9795	41.20
Third	26533	1113	10.55%	2067	3.3153	23.84
Fourth	26414	1990	18.86%	4057	3.6082	13.27
Fifth	25109	6493	61.55%	10550	4.0233	3.87
Total	130319	10550	100.00%			

*n=cumulative patents

(b) The Drug Industry

Zone	Citation times	Number of Patent	Percentage of Patent	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	127396	1808	2.39%	1808	3.2572	70.46
Second	131270	4361	5.76%	6169	3.7902	30.10
Third	115261	6658	8.80%	12827	4.1081	17.31
Fourth	128092	13637	18.01%	26464	4.4227	9.39
Fifth	130438	49238	65.04%	75702	4.8791	2.65
Total	632457	75702	100.00%			

*n=cumulative patents

(c) The Semiconductor Industry

Zone	Citation times	Number of Patent	Percentage of Patent	Cumulative patents (=n)	Log(n)	Average of patent to citation
First	375586	4081	2.66%	4081	3.6108	92.03
Second	361947	8536	5.56%	12617	4.1010	42.40
Third	386928	16020	10.43%	28637	4.4569	24.15
Fourth	366078	27474	17.89%	56111	4.7490	13.32
Fifth	366460	97485	63.47%	153596	5.1864	3.76
Total	1856999	153596	100.00%			

*n=cumulative patents

In LD industry, the three zones are compiled into table 3.3(a) according to the one fifth of total forward citations that is nearly equal to 26,064 times. Then the numbers of patents (R_i, i=1, 2, 3, 4, 5) in the first zone and succeeding zones are R_1:R_2:R_3 R_4:R_5=315:639:1,113:1,990:6,493=315(1:2.02:3.53:6.32:20.61) which the constant is C=714. And the multiplier (r) might not be generally computed. Furthermore, the average citation ratio of patent to citation is also computed in each zone. The value in the first zone is about 82.33, and then reduced to 41.20, 23.84, 13.27, and 3.87 in the succeeding zones. This reveals the phenomenon that the patents in the first zone have more relative highly impact and value to a LD technology comparing with the results above.

In the drug industry, the five zones are compiled into table 3.3(b) according to the one fifth of total forward citations that is nearly equal to 26,063 times. Then the numbers of patents (R_i, i=1, 2, 3, 4, 5) in the zones are R_1:R_2:R_3 R_4:R_5=1,808:4,361:6,658:13,637:49,238=1,808(1:2.03:3.53:6.32:20.61) which the constant is C=1,808. And the multiplier (r) might not be generally computed, too. Moreover, the average citation ratio of patent to citation is also computed in each zone. The value in the first zone is about 70.46, and then reduced to 30.10, 17.31, 9.39, and 2.65 in the succeeding zones. This reveals the phenomenon that the patents in the first zone have relative more highly impact and value to a drug technology, such as LD industry, and the patents belonged to the fifth zone have relative lowest influence to this technology.

In the semiconductor industry, the five zones are compiled into table 3.3(c) according to the one fifth of total forward citations that is nearly equal to 371,400 times. Then the numbers of patents (R_i, i=1, 2, 3, 4, 5) in the zones are R_1:R_2:R_3 R_4:R_5=4,081:8,536:16,020:27,474:97,485=4,081(1:2.09:3.92:6.73:23.89) which the constant is C=4,080. And the multiplier (r) might not be generally computed, also. In fact, the average citation ratio of patent to citation is also computed in each zone. The value in the first zone is about 92.03, and then reduced to 42.40, 24.15, 13.32, and 3.76 in the succeeding zones, respectively. This reveals the phenomenon that the patents in the first zone have relative more highly impact and value to a drug technology like LD and drug industry are, and the patents belonged to the third zone have relative lowest influence to this technology.

3.7 Analysis on Patent Forward Citation Proportionalities – into Five Zones

From the results above, the relative distribution of each number can be more clearly discussed. There would be a percentage of 3% of granted patents in first; 6% of granted patents in second and the following were 10%, 18% and 63%. All the zones' patents contained the same percentage of 20% about citations. Thus, from the view of economics, there would be a relative highly marginal productivity for the patents in the first zone because it cost relative low number of patents reach the same portion of forward citation. In the other words, the patents in the fifth zone should be less important because it cost much more patents to contain the same portion of forward citation.

A firm had more of these patents in first zone might meant it had more core technology in the specific technology and would be the leader firm of the industry in R&D development. In comparison, the patents in the fifth zone was less valuable and could be viewed as almost not yet be cited as the forward citations was just less then 5 times on average in our cases. This state might reveal these patents had no valuable technology and knowledge for the development of the specific technology. A firm had more of these patents might meant it took much R&D resource to the development of unimportant technology. Then it could be set up a criterion that the firms or countries should try to add the value of the patents and make effort to have the first-zone-patents because this meant the firm or country had the great influence in a specific technology if they dominate more of the first zone's patents. It also could be the goal in R&D developing that a firm should reach.

Chapter 4 Analysis on Scattering Pattern of Patents Data

4.1 Growth Pattern by Logarithm View

In this discussion, it was discovered that there would be an accordable results with a Groos droop in each industry's data distribution. Besides, there would be a measurable thing to be discussed in terms of patterns' growth trend under the logarithmic scale.

The logarithm value of the number of cumulative patents was also revealed in order to verify the scatter and curve from Bradford's law in terms of patents and forward citations. There would be the pattern of the "Bradford curve of each industry" which was drawn by cumulative citations (vertical axis) to the logarithm value about the number of cumulative patents (horizontal axis). In the meantime, Groos droop was also verified in this study by observing weather there would be an inverse growth leading to a curve which has an inflection point, so that the positive slope starts decreasing progressively in the third zone from the three-zone-view. The expectation of this observation would be like the curve CD' in the following figure 4.1:

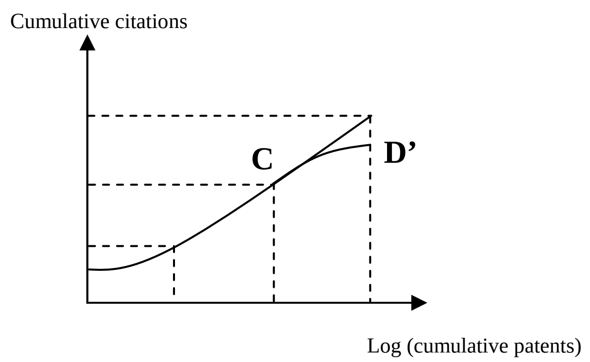

Figure 4.1 The Bradford Curve with Groos Droop of Industry

At the same time, there would be some consistent results in patents discussions with the discoveries of Bibliometrics. Groos droop was also verified in this study by the following discussions. The three Bradford curves were illustrated in figure 4.2(a), figure 4.2(b) and figure 4.2(c) by the patent data in table 2.1(a), table 2.1(b) and table 2.1(c), respectively. From the vertical axis, the three numbers of cumulative citations have already separated the three portions.

In the LD industry, the curve of the first zone, which has the log scale from 0 to 2.8537, is clearly exponentially growing as a convex curve that has the increasing progressively positive slope from the origin. Meanwhile, the log values could be clearly found in the compiling of table 3.3. This phenomenon is generated, as there are a relative lower number of patents containing relative higher number of forward citation. Therefore, the convex curve is presented exponential growth after the transformation of logarithmic being computing.

In the second zone, the curve has the log scale from 2.8537 to 3.4036 presenting a straight line as the growth of the phenomenon made in terms of a relative lower number of patents containing relative higher number of forward citation, is getting weaker. Hence, this reverses that there is a growth generating a linear relation of positive slope.

In the third zone, the curve has the log scale from 3.4036 to 4.0233 presenting an inflection point rather than a straight line, which Bradford proposed in 1943. This is made due to a relative higher number of patents containing relative lower number of forward citation. So that the positive slope starts decreasing progressively finally and the result also verifies the argument of Groos proposed, that is, the phenomenon of Groos droop.

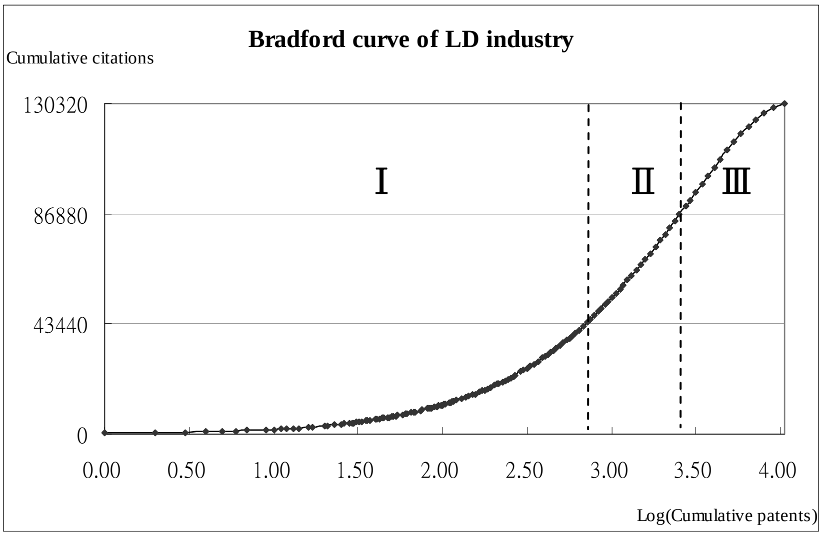

Figure 4.2(a) The Bradford Curve of LD Industry

In the drug industry, from the origin the curve of the first zone that has the log scale from 0 to 3.6413 is clearly exponentially growing as a convex curve, which has the increasing progressively positive slope. This phenomenon is generated, as there are a relative lower number of patents containing relative higher number of forward citation. Therefore, the convex curve is presented exponential growth after the transformation of logarithmic being computed.

In the second zone with the log scale from 3.6413 to 4.2292 presenting a straight line as the growth of the phenomenon made in terms of a relative lower number of patents containing relative higher number of forward citation, is getting weaker. Hence, this reverses that there is a growth generating a linear relation of positive slope.

In the third zone with the log scale from 4.2292 to 4.8791, presenting a curve that has an inflection point revealed by Groos. This is made due to a relative higher number of patents containing relative lower number of forward citation. So that the positive slope starts decreasing progressively finally and the result also verifies the argument of being proposed, that is, the phenomenon of Groos droop.

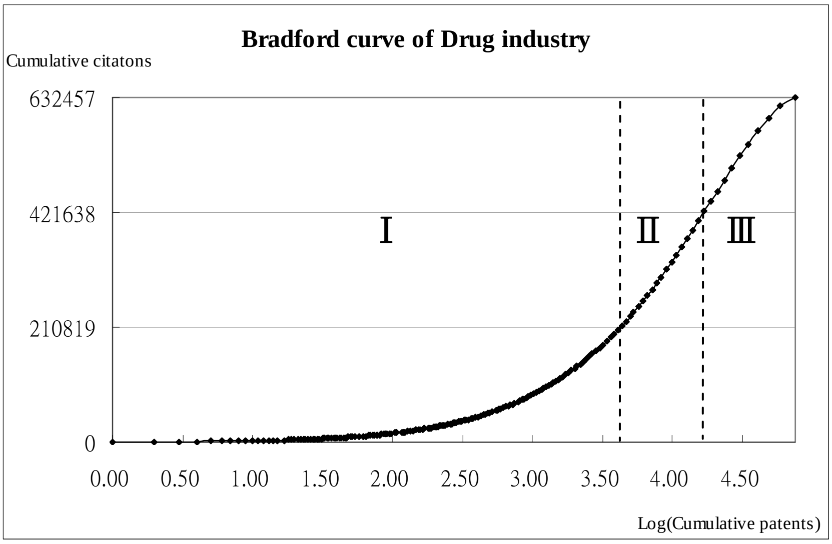

Figure 4.2(b) The Bradford Curve of Drug Industry

In the semiconductor industry, from the origin the curve of the first zone that has the log scale from 0 to 3.9727 is clearly exponentially growing as a convex curve, which has the increasing progressively positive slope. This phenomenon is generated, as there are a relative lower number of patents containing relative higher number of forward citation. Therefore, the convex curve is presented exponential growth after the transformation of logarithmic being computed.

In the second zone with the log value from 3.9727 to 4.5460 existing a straight line as the growth of the phenomenon made in terms of a relative lower number of patents containing relative higher number of forward citation is getting weaker. Hence, this reverses that there is a growth generating a linear relation of positive slope.

In the third zone with the log value from 4.5460 to 5.1864, existing the curve that has an inflection point revealed by Groos. This is made due to a relative higher number of patents containing relative lower number of forward citation. So that the positive slope starts decreasing progressively finally and the result also verifies the argument of being proposed, that is, the phenomenon of Groos droop.

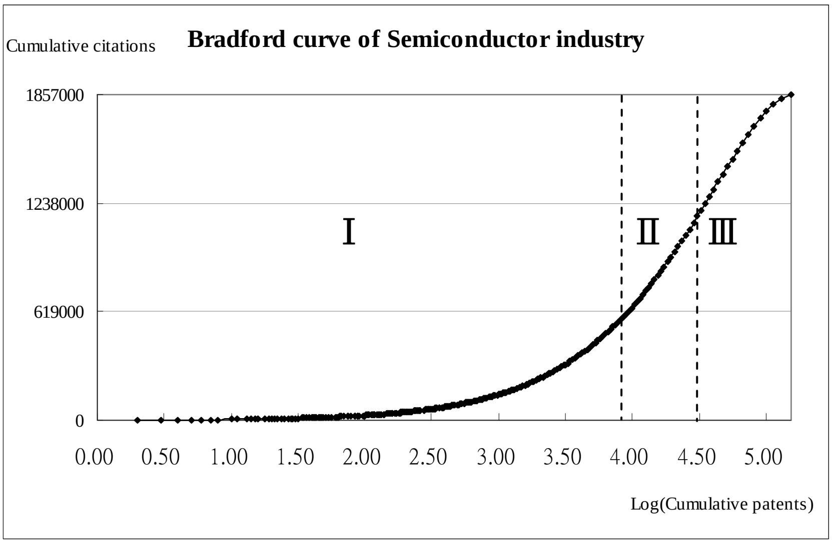

Figure 4.2(c) The Bradford Curve of Semiconductor Industry

4.2 Curve Growth with Logarithmic Scale

Finally, the phenomena of Groos droop in the discussion would be precisely verified in the numerical way while the log value shown in the Bradford curve was taken as a relative scale. By the meaning of patent data distributing, the longer distance of first zone's growth curve extended (it could be clearly measured as a difference between two log values), the higher number of lower patents containing the larger number of forward citation. The meaning of scale was also verified in the state of second zone. The longer extended curve could be explained that the growth of a relative lower number of patents containing relative higher number of forward citation was getting weaker in the second zone. Especially, if there would be an inflection point, that is, the Groos droop, the discussion could be elaborated more deeply.

There would be two discussions in the third zone under the existence of an inflection point. Before reaching the inflection point, the fact was that the state of linear relation reflected from the second zone was getting weaker. Unto the inflection point, the marginal value of the number of cumulative citations was decreasing growth related to a stably growth of number of patent. Therefore, the longer of the curve extending the higher number of patent containing fewer forward citations making the more unequal distribution of patents to the forward citations.

After the discussions of above, the characteristics of patent data in the three industries were generally consistent. The results of unequal distribution between patents and forward citations could be first observed. So the scattering of patents in the three industries were similar and had the same Bradford curves like “S” shape. It could be surely discovered that the Groos droop was also presented in the Bradford curve in the third zone. The numerical results were also discussed in the following sections.

The positions of log value in the three Bradford patterns were combined with the relative ratio of patents distributed, which contained the equal ratio forward citation about 33% in the three industries were discussed in the table 2.1 previously.

When the log value was taken as relative distance, the distance of first zone’s growth curve (it could be clearly defined as an exponential growth curve) was the longest one in the semiconductor industry which had the bigger value (3.9727), however, the reason was not just because the number of patent was the largest one. After the logarithmic transformation of the number of cumulative patents, the fact was that there would be a higher number of lower patents containing the larger number of forward citations. The fact was also soon be verified in the state of second zone. The longest extended curve (which was clearly defined as a straight line growth) in the second zone among the three industries was the line in the drug industry (which had the bigger minus value (3.6413-4.2292=-0.5879). This could be explained that the growth of a relative lower number of patents containing relative higher number of forward citation was getting weaker in the second zone, stably extended and longest in the drug industry. Finally, the longest extended curve in the third zone (which was defined as an inversely exponential growth curve) was in the drug industry still (which had the bigger minus value (4.2292-4.8791=-0.6499).

4.3 Inflection Behaviors by Groos Droop

In the study, it was found there would be an inflection point in the curve of the third zone in the three industries. For the part, it was more clearly discussed about the distance after the inflection point in the third zone by the table 2.1(a), table 2.1(b), and table 2.1(c) as shown.

Table. 4.3 The Marginal Value after Inflection Point

(a) The LD Industry

LD industry		
Cumulative citations	**log(Cumulative patents)**	**△Cumulative citations**
118253	3.7655	-
121368	3.8096	3115
124116	3.8536	2748
126681	3.9027	2565
128843	3.9578	2162
130319	4.0233	1476

(b) The Drug Industry

Drug industry		
Cumulative citations	**log(Cumulative patents)**	**△Cumulative citations**
547362	4.5413	-
571338	4.6104	23976
594645	4.6861	23307
615953	4.7723	21308
632457	4.8791	16504

(c) The Semiconductor Industry

Semiconductor industry		
Cumulative citations	**log(Cumulative patents)**	**△Cumulative citations**
1675034	4.9099	-
1719474	4.9549	44440
1761442	5.0028	41968
1800772	5.0559	39330
1833530	5.1144	32758
1856999	5.1864	23469

The columns were the cutting listed from the table 2.1(a), table 2.1(b), and table 2.1(c). The marginal value of cumulative citations after the inflection point was computed in the third column, respectively. From the three tables above, the Groos droop could be proved in terms of numerical method as the number of cumulative citations was increasing slowly relate to "a constantly increasing in the log value of cumulative patent". This meant the marginal value of the number of cumulative citations was decreasing growth. Additionally, the log value of cumulative patents was shown so that the longest extended of the growth curve could be found in the drug industry which had the bigger distance value (4.8791-4.5413=0.2687). The phenomena told that there was a relative higher number of patents containing relative lower number of forward citation were strongly emphasized in the drug industry.

Meanwhile, with different criterions of separation, there would be some more clearly proportional relations better than the multiplier relation Bradford supported, among them being about 6%, 16%, and 77% granted patents in each zone in the three-zone-method, being about 4%, 9%, 19%, and 68% granted patents in each zone in the four-zone-method, and being about 3%, 6%, 10%, 18%, and 63% granted patents in each zone in the five-zone-method. However, there wouldn't be a clear separation on zones' discussions about how many zones should be done, but this revealed an outline on these elaborations.

4.4 The Trends of Data Distribution on Curve Fitting

With the discussions of data by separations in three, four, and five zones, however, it was found that there might be a consistent data distribution among these industries. It was supposed that the data distribution of three industries would be similar, thus, the curve fitting of Bradford curve was discussed. First, the data distribution of three industries on Bradford curve manifested the whole trend of patent. As figure 4.4 shown, the cumulative citations were transferred into percentage via dividing by the total number of citation from the beginning of accumulation in the vertical axis, while the log value of cumulative patents were transferred into percentage, via dividing by the total number of patents' log value from the beginning of accumulation in the horizontal axis. Therefore, the three Bradford curves with different scales could be compared in the same scale. In fact, it was obvious that there would be a similar data distribution among the three industries. From the origin to the end of data accumulation, there was a "S" shaped curve with "Gross droop" at the same time. Moreover, the middle of the three curves had different distributions. Nevertheless, there would be the same Bradford curve trend among them.

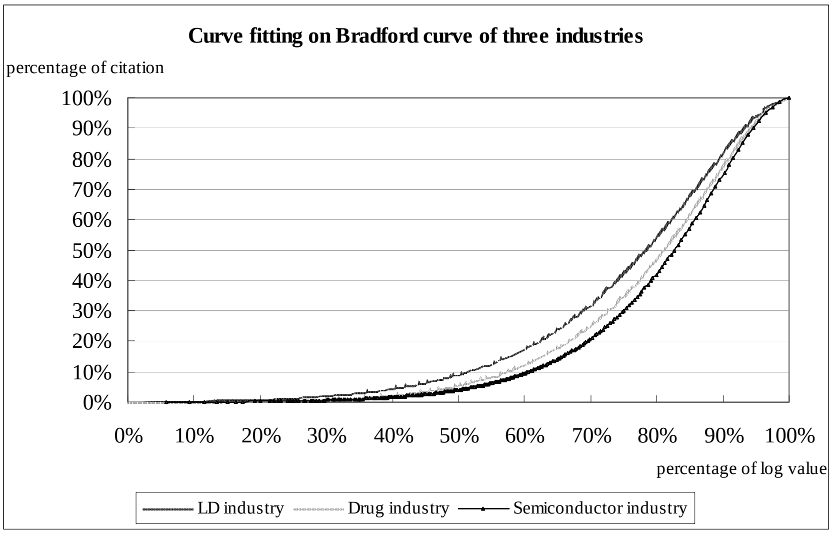

Figure 4.4 Curve Fitting on Bradford Curve of Three Industries

Additionally, it was supposed that there would be the same trend only in terms of the data scattering from the discussions above, thus the curve fitting of data scattering was elaborated as well. Base on the previous discussions of data scattering, the cumulative citations were transferred into percentage via dividing by the total number of citation from the beginning of accumulation in the vertical axis, while the cumulative patents were transferred into percentage, via dividing by the total number of patents from the beginning of accumulation in the horizontal axis. As the figure 4.5 shown, it was observed that there would be a closely and similar straight line among the three industries. Afterwards, the trends of data distributions also verified the research results discussed in the previous sections about each zone's value.

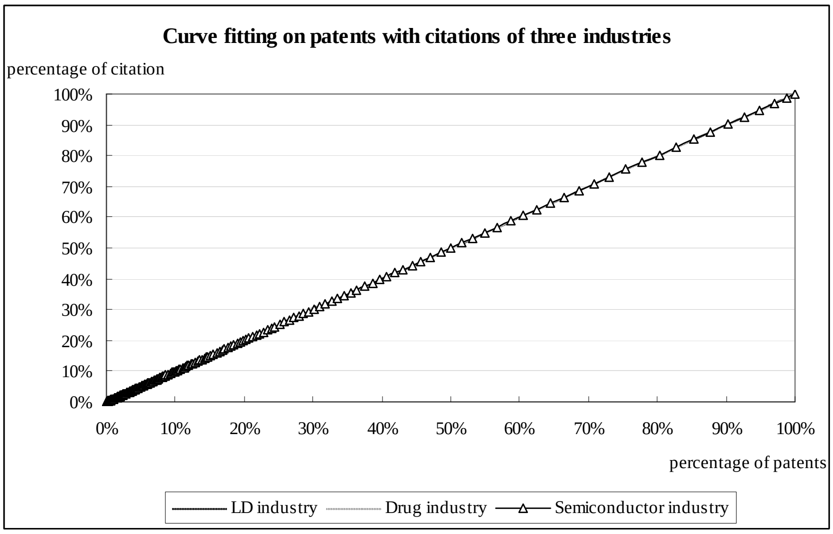

Figure 4.5 Curve Fitting on Patents with Citations of Three Industries

Chapter 5 Conclusions

The objective of this research is to set up a criterion for classifying the patents based on their importance and value. Bradford's law provided a practical method for us to find this criterion and verified the unequal distribution of patent data related to forward citation.

From the discussions of above, the validity of quoting Bradford's law and an unequal distribution, like the bibliometrics, were proved. According to the Bradford's law, it was verified that the phenomena of an unequal distribution of those lower patents dominated larger forward citations, and these were established on the scattering patterns, as well. With the elaborations on separated zones differently, we found the patents in the first zone had the most influence and considerable meaning to a specific technology, like the liquid display of LCD, drug and semiconductor because we assumed a patent was cited more frequently by others had a viewable and valuable technology.

Referring to the Bradford's idea on the management of library, it could be also more effectively and economically to the management of patents. It was supposed that many studies, like the discussion of firm's competitiveness, should use the patents of the first zone, such as considering that how many patents in the first zone that firm should possess rather than pursuing the numerical count of all the patents since the value in each patent were different. Therefore, the other studies about the prediction of firm's performance could modify the independent variable according to the criterion made by Bradford. Furthermore, all the growths of firm's granted patents could be taken as a Bradford curve to discover the overall development pattern, and as a managing criterion about how to point out what patents contained the important knowledge. Finally, this study offered a resource allocation criterion like the ABC method in the inventory management to find the valuable patents and technologies.

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