American Journal of Industrial and Business Management, 2015, 5, 557-564
Published Online August 2015 in SciRes. http://www.scirp.org/journal/ajibm
http://dx.doi.org/10.4236/ajibm.2015.58055

Scientific Research Publishing

The Innovation Study of Japan and US Semiconductor Companies

—Internal Invention and Non-Internal Invention

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Received 11 March 2015; accepted 22 August 2015; published 25 August 2015

Abstract

The negotiations with other firms (opponents) such as licensing are likely to take action as a routine-work of certain actions. It will make decisions in some paradoxical situation not only patent infringement lawsuit, but also cross-licensing negotiations in strategic business. It should be noted that inventions were regarded as only performance of R&D (Research & Development), which called them inventions for technological strategy. However, there exist inventions resulting from other factors, which are exactly defined as inventions for patent strategy; we shall call them inventions for patent strategy. So then, we picked out for several US and Japanese semiconductor manufacturers, and so our analysis separated out the number of inventions motivated by technological strategy within the whole set of inventions. Unlike other types of property, IP (intellectual property) assets lack clear property lines and every type of intellectual property you can own comes with connections to other valuable innovations. These ownership rights are also exactly changing. They are embedded in a dynamic technology context, one in which new innovations and new advances are constantly added. One of the best ways to examine that context is observing the legal property provided by patent citations, the references to the prior IP on which the patented inventions build. Patent citations are very important because they make the relationships among technologies and related property rights. The objective is to show that firms make inventions not only on technological factors, but also on patent strategy. Simple analysis method is proposed to identify how many non-internal inventions are filed for patents.

Keywords

Invention, Patent, Licensing Business, Non-Internal Invention, Patent Citation

How to cite this paper: Inuzuka, M. (2015) The Innovation Study of Japan and US Semiconductor Companies. *American Journal of Industrial and Business Management*, **5**, 557-564. http://dx.doi.org/10.4236/ajibm.2015.58055

1. Introduction

Patent is an important resource for many firms, yet its importance has not been widely recognized in the business administration until now. This paper regards patents as one of the most important resources of firms. The context of the idea of this paper has grown along with the contents of the RBV (resource based view), attributing a firm's sustainable competitive advantage to using the resources that meet certain criteria, such as the Capability [1], and VRIO[1] [2].

The basic idea behind the resource based view (RBV) is that there is a significant positive correlation, in some cases a temporal causation, between certain firms' resources and certain measures of firms' performances. The RBV is built on the following two assumptions. First, resource based model assumes that strategic resources should be heterogeneous compared to other firms within an industry. Second, this resource based model assumes that the resources may not be perfectly mobile across a firm, and the imperfect mobility can be long lasting because the strategic resources are heterogeneous [2].

This paper analyzes corporate actions such as inventions, patent applications and licensing activities. In particular, this thesis focuses on the differences between internal inventions and non-internal inventions (inventions results from factors other than technological factors are collectively called non-internal inventions). This thesis aims to show that firms make inventions not only for technological factors, but also for licensing factors. This thesis would also identify that many non-internal inventions are actually filed for patents.

2. Approach

Hall, Jaffe, and Trajtenberg, in their paper published in 2005, analyze the patents of the semiconductor industry in the United States. According to the study, the most important knowledge to rate corporate value is (Research and Development) which cand be interpreted not only as a description of the enterprise value in stock, but also as the number of patent and patent filing, that shows the degree of research and development activities.

Patent, comprised of patent citations and patent filing, mainly come from firms' R&D activities [3]. This thesis, particalarly, tocus on patent citations. Just as an academic paper cites existing papers, existing patents are cited in filing a patent. For example, in **Figure 1**, there are four US patents related to semiconductors, which have citing and cited relationships with each other. In each ellipse, i) patent owner, ii) grant year, and iii) registered patent number is noted. Look at the centrally located patent #US6434073 (hereafter referred to as patent 073; likewise, other patent numbers are abbreviated to their last three digits). This patent 073 was issued by Intel in 2001, and the following can be observed: 1) Patent 073 cites patent 474 of TI-Texas Instruments. 2) Patent 073 is cited by patent 023 of Hynix acquired in 2008. 3) Patent 073 is also cited by patent 889 of Intel itself. This type of citation is called a "self-citation."

Computer firms and research institutions in semiconductor industry utilizes the fruits of innovations of the major three associations, ISSCC, IEDM, and VLSI Symposium, which mutually exchange the knowledge of new technologies and development capabilities of semiconductor manufacturing [4].

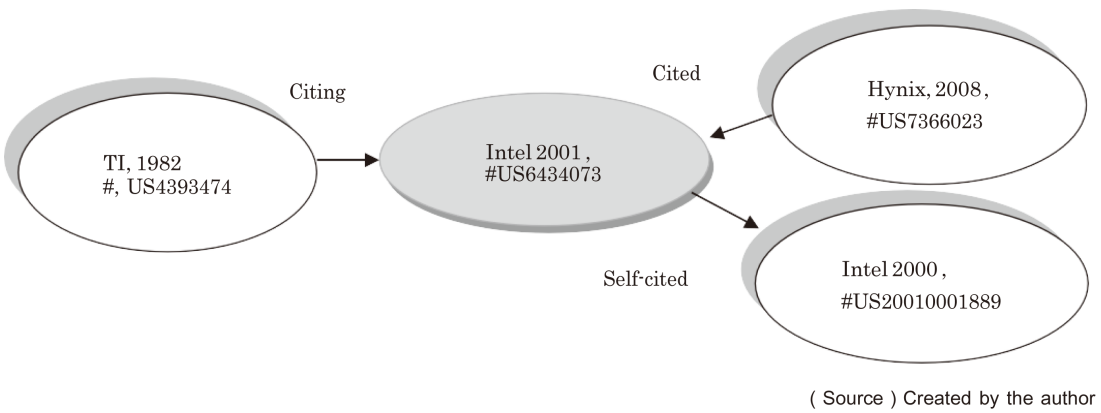


Figure 1. The relations between citing patent and cited patents.

[1]VRIO, analysis by J. B. Barney, is the proposed of core framework RBV; economic value (value), scarcity of (rarity), imitation of (inimitability), organization (human resources).

3. Survey Data

Semiconductor patents data used for this analysis contains the data from 1963 to 2002. Generally, the major indicators to assess a firm's capability for the creation and development of new technology are the data on R&D, such as the number of articles cited in patent applications. This study focuses on US patents, which are issued by the United States Patent and Trademark Office (USPTO). The data show the relations between the citing and the cited patents. This research utilizes the data of six million patents issued by the USPTO between 1963 and 2002, provided in a form on the webpage of the National Bureau of Economic Research (NBER) and in a CD-ROM appended to a book by Jaffe and Trajtenberg [5]. This research also uses the data from a private sector's database service company named Patsnap[2], as a decision making tool of computer application. A patent data set contains the following information: patent number, grant year, grant date (the number of days passed since January 1, 1960), application year, home country of the first inventor, state of the first inventor assignee identifier, and assignee type (individual, corporate, or government, main US patent class, and the number of claims).

The data set of this study contains the US patents registered from 1963 to 2002; sub-category code 46 of Semiconductor Devices 4 classified into USPTO primary classes 257, 326, 438, and 505 defined as "semiconductor devices" by Hall, Jaff and Trajtenberg: and filed by the top sixteen US and Japanese semiconductor manufacturers ranked by the number of average self-citation [6]. The sixteen semiconductor manufacturers consist of six US firms: Micron Technology, Intel, Motorola, IBM, Advanced Micro Devices (AMD), and Texas Instruments (TI); and ten Japanese firms Toshiba, Hitachi, Panasonic, Fujitsu, Mitsubishi, Sharp, Sony, NEC, Rohm and Sanyo. Similar to academic papers, the amount of patent citation indicates the importance of a patent.

The result of this research shows that the mean value of the average number of citations for US, companies, 9.723, is remarkably higher than that for Japanese companies, 5.449. Both average values are statistically significant, ($t = 0.6003$, $p < 0.01$). Each of the Japanese three firms Toshiba, NEC and Mitsubishi possesses 1829 patents, 1992 patents, 1870 patents, respectively. However, the mean value of the number of the average self-citation of the three firms was not so high. What does this data indicate?

4. Hypothesis

Using the concept of the cited patent and self-citation ratio, we can set up the following two hypotheses.

4.1. Hypothesis 1

When a firm generates inventions for technological strategy in its laboratory, the higher the frequency of patent filing, the higher the self-citation ratio of the patents filed.

Given the complicated factors, we can easily imagine that not all inventions are generated for technological strategy. Therefore, the purpose of this study should be not only to confirm this hypothesis, but also to specify the outlying firms, which are likely to generate inventions for patent strategy.

Though firms do not open its patents' technical information for two years for public, a firm may generate technical breakthroughs in R&D, and several new inventions can be generated within a short period.

4.2. Hypothesis 2

During a period when a firm's self-citation ratio becomes higher, the average number of citations of the patents possessed by the company also becomes higher.

This hypothesis indicates that the numbers of citations are associated with the self-citations ratio. In the latter part of this paper, we further discuss firms' patent strategy and corporate behavior through several qualitative data analysis.

5. Analysis

Here, we try to verify the hypothesis 1. It must be noted that the greater number of patents granted during the specific period (from 1963 until 2002) implies a higher frequency of patent filing. The numbers of the patents and the self-citation ratio in **Table 1** are graphed as points in the (x, y) plane to produce the scattered diagram of

[2]The Patsnap created patent service for the company used by United States Patent Office's database and provides its solution service all over the world. (June 19th, 2014, Access: http://www.patsnap.com/).

Table 1. Number of average self-citation by firm.

#		Name of firm	Number of patents (from 1963 until 2002)	Number of citation	Number of self-citation	Number of average self-citation	Number of average self-citation (by two countries)
1	American firms	Micron Technology	15.26	18,536	0.246	12.147	9.7232
2		Intel	365	4021	0.098	11.016	
3		Motorola	1439	13,087	0.248	9.095	
4		IBM	1390	12,104	0.252	8.708	
5		AMD	1023	8898	0.205	8.698	
6		TI	1556	13,497	0.225	8.674	
7		Toshiba	1829	12,989	0.171	7.102	
8	Japanese firms	Hitachi	1037	6634	0.129	6.397	5.6705
9		Panasonics (Matsushita)	624	3848	0.079	6.167	
10		Fujitsu	889	5387	0.085	6.060	
11		Mitsubishi	1870	11,195	0.125	5.987	
12		Sharp	494	2928	0.055	5.927	
13		Sony	562	3298	0.075	5.868	
14		NEC	1992	10,897	0.115	5.470	
15		Rohm	213	845	0.034	3.967	
16		Sanyo	186	485	0.048	2.608	

Source: Created by United States Patent Office (USPTO).

Figure 2. In this figure, firms are plotted on the coordinate system with the number of patents on the horizontal axis (x-axis) and the self-citation ratio on the vertical axis (y-axis). In the coordinate plane, the black dots "•" represent the US and Japanese semiconductor firms. In **Figure 2**, the relation is clear from the plot of the data. The three Japanese firms on the right side of the coordinate plane—Toshiba, NEC, and Mitsubishi Electric—are clearly outliers. The other thirteen firms excluding these three fall nearly along a straight line. The most widely used method for fitting lines to data is called the least-squares regression analysis. Using the self-citation ratio as a dependent variable y and the number of patents as an independent variable x, the following result is given.

$$y = 0.000145x + 0.0053 \text{ Adjusted } R^2 = 0.8435$$

$y = 0.000145x + 0.0053$ Adjusted $R^2 = 0.8435$. This result is accurate with a calculation error of less than 0.1 percent. Therefore, the self-citation ratio increases in proportion to the number of patents obtained during a specific period. The result supports the hypothesis 1, that is, these thirteen firms are considered to generate inventions mainly for technological strategy. Of these thirteen firms, US firms show a tendency to have both a high number of patents and a higher self-citation ratio, except for Intel. In contrast, Japanese firms show a tendency to have both a lower number of patents and a lower self-citation ratio. Therefore, compared to Japanese firms, US firms probably have a higher rate of R&D, which results in a higher self-citation ratio. Generally speaking, a high self-citation ratio implies a quick pace of R&D. Meanwhile, the three Japanese firms, Toshiba, NEC, and Mitsubishi, having the greatest numbers of patents in **Figure 2**, are outliers. They are nearly equal in terms of the number of patents they possess, and the relatively lower number of their self-citation ratio.

The analysis strongly suggests that inventions for patent strategy have a direct correlation with a greater number of self-citation. Also, outliers from the hypothesis 1 are clearly identified. The deviation from the regression line in **Figure 2** show that patents filed by the three Japanese firms are patents of inventions for patent strategy. Follow-up interviews [7] were conducted on two of the three outlying Japanese firms. The inquiry revealed that during the sample period, the management urged the R&D department to increase the number of patent filings and the firms' manager assigned a quota for the number of patent applications for their researchers.

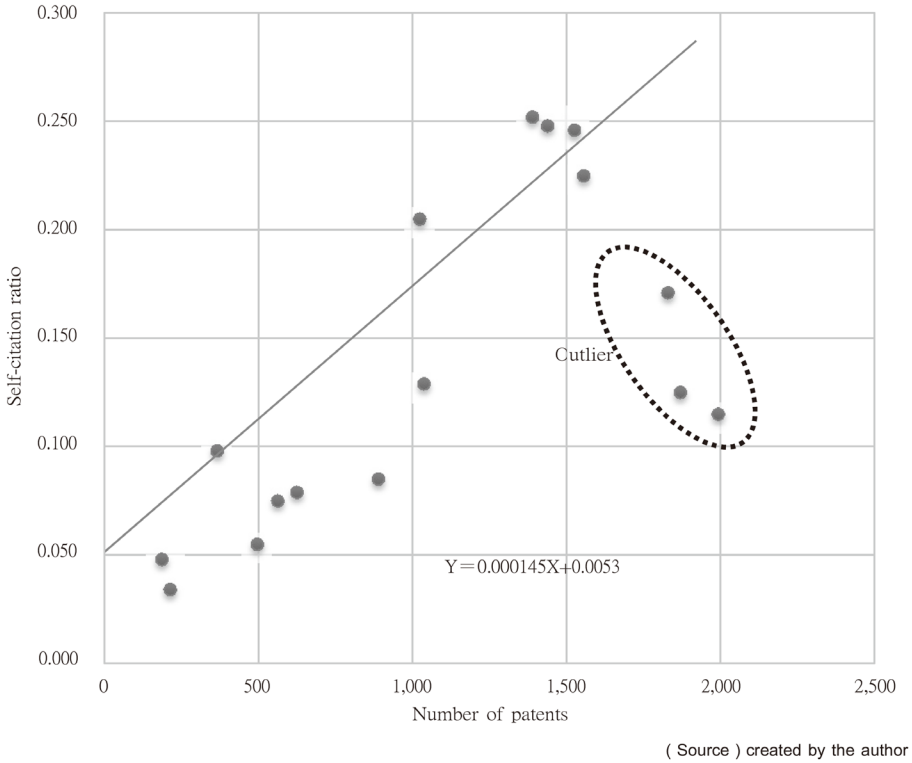


Figure 2. The relationship between self-citation ratio and number of patents.

Here, we move onto verify the hypothesis 2. **Figure 3** show the results of multiple regression analysis for hypothesis 2. Basic statistics suggest that coefficient of 0.5174% and 0.1% are significant level. Also, the partial correlation coefficient 0.7414 is positive correlation between self-citation ratio and number of citations.

$$y = 0.023x - 0.026 \text{ Adjusted } R^2 = 0.5174$$

$y = 0.023x - 0.026$ Adjusted $R^2 = 0.5174$. This result is accurate with a calculation error of less than 0.1 percent. Therefore, the self-citation ratio increases in proportion to the number of average self-citaion during a specific period. This supports the hypothesis 2, that is, the result of the analysis of the sixteen firms is a proof of the strong correlation between self-citation ratio and average number of citations. US firms show a tendency to have both a higher self-citation ratio and the greater average number of citations[3].

6. Interpretation of the Hypotheses and Their Implications

6.1. Self-Citation Ratio of Patent

Here, we discuss the findings of the previous analysis that the larger number of patents registered bring to a greater number of self-citation ratio of patent for a period of time. That is, these thirteen out of sixteen firms could consider to be generating internal inventions. There is general trend that indicate a higher self-citation ratio compared to Japanese firms. On the other hand, Japanese companies tend to show a lower self-citation ratio and average number of citation. In particular, three outlier Japanese firms are strongly suggested to be generating non-internal inventions.

The patents for the non-internal inventions are utilized not only for their own products and services.

Third party firms also utilize the inventions. Takahashi stated that, out of all luventions, there are about 3% -

[3]Each data of the Japan-US semiconductor companies shown in Figures 7. (self-citation ratio *x*, the average number of citation *y*) is as follows. United States 6 companies—Micron Technology (0.246, 12.147), Intel (0.098, 11.016), Motorola (0.248, 9.095), IBM (0.252, 8.708), AMD (0.205, 8.698), TI (0.225, 8.674), and Japanese 10 companies—Hitachi (0.129, 6.397), Toshiba (0.171, 7.102), Panasonic (0.079, 6.167), Sharp (0.055, 5.927), Fujitsu (0.085, 6.060), Mitsubishi Electric (0.125, 5.987), NEC (0.115, 5.470), Sony (0.075, 5868), Rohm (0.034, 3967), Sanyo (0.048, 2608).

4% of non-internal inventions [8]. While considering Companies' motivation and benefits in increasing the number of patents, we would discuss why non-internal innovation bring benefits for companies.

6.2. Relationship between Self-Citation Ratio and Average Number of Citations

Figure 3 note the relationship between self-citation ratio and average number of citations. The self-citation ratio and average number of citations are graphed as points in the (x, y) plane to produce the scattered diagram of **Figure 3**. In this figure, the firms are plotted on the coordinate system with self-citation ratio on the horizontal axis (x-axis) and average number of citations on the vertical axis (y-axis).

These firms are located along with regression line, and can be classified into four categories, which are:

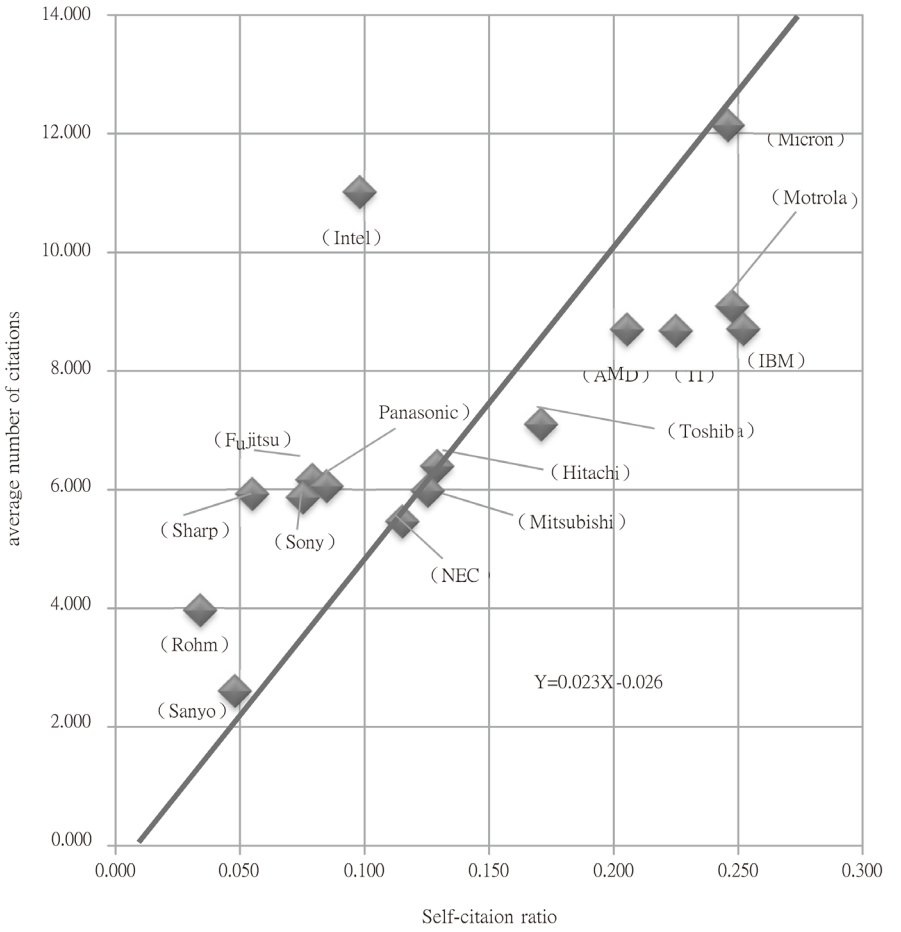
a) Nine Japanese firms show low self-citation numbers and low average number of citations.

b) Only one Japanese company shows high self-citation ratio and low average number of citations.

c) One US firm indicates normal self-citation ratio and low average number of citations.

d) Four US firms demonstrate high self-citation ratio and low average number of citations.

In the past forty years, Japanese semiconductor firms relatively did not have attractive patents. Due to the lack of basic patents, Japanese semiconductor firms failed in attracting much resources, and could not demonstrate its leadership in R&D in the field. As a result, the sales and the profits of Japanese semiconductor-related products have slowly fallen down from 1963 to 2002, and many Japanese semiconductor manufacturers had to produce household appliances and electronics products. Thus, the main characteristics of Japanese semiconductor industry during the past forty years has been the lack of hundreds of necessary product licenses [9]. This is the reason why many Japanese semiconductor firms are taking licensing strategy.



(Source) created by the author

Figure 3. Relation between self-citation ratio and average number of citations.

7. Cross-Licensing Agreement Category

If a firm needs to use a license obtained by another firm, the simplest and the easiest way is to pay for the patent rights. However, this type of peaceful license negotiation is extremely rare. A typical license negotiation begins with a patent infringement warning. If a firm receives a patent infringement warning and is pressured for making a decision on whether or not to accept the licensing, the firm should consider the following costs:

a) The costs of R&D to avoid that patent. b) The cost of submitting an appeal-for-invalidation claim on that patent. c) The legal costs needed for the patent infringement lawsuit.

If these avoidance costs for the patent are more than the license fee, the firm usually decide to accept licensing. In other cases, the firm should promote other patent strategies that do not contravene against the existing patents. However, it is usual that multiple patents, including other firms' patents, are needed to manufacture one product. Thus, it is inevitable that other manufacturers in the same market to produce similar products, infringing on competitors' patents mutually. In this type of industry, agreements to mutually use multiple patents are often made. Also, some firms commonly pursue cross-licensing agreements in order to cancel out mutual licensing fees.

In negotiating a cross-licensing agreement, the number of patents filed by firms are important. In many cases, negotiating firms count the respective numbers of patents and charge license fees based on the difference in those numbers. Of course, many firms not only count the number of patents, but also consider the number of journal papers and academic reports. However, the number of patents is of the prime importance, and the qualitative value of patents are not as important. As a result, when the number of patents exceeds a certain range, the license fees often cancel each other out and become close to zero. The cross-licensing agreement is like a mutual nonaggression treaty in diplomatic strategy [10].

If the first priority of a firm is to complete a cross-licensing contract, after the conclusion of the contract, there is an option to abandon small patents except for key patents. Thus, in negotiating for a cross-licensing contract, although the number of patents each company possesses is most important, firms also need to consider the qualitative value of each patent.

According to Kishi and Takahashi's study [8], an example of a firm's abandonment of its patents is "the patent 404, or "the method of growing a semiconductor crystalline film of nitride compounds" (Japanese patent number 2628404, hereafter referred to as patent 404).

This so-called blue LED lawsuit was fought over from 2004 to 2005, attracting a huge public attention. One of the inventors of the blue LED, Shuji Nakamura who gained Novel Physics Prize in 2014, sued his former employer, Nichia Corporation in August 2001. On January 30, 2004, the first trial in the Tokyo District Court judged that the incredible amount of 60.4 billion yen should be paid as the compensation for Nakamura's invention, and it ordered Nichia to pay Nakamura the entire amount of the 20 billion yen he claimed.

Almost one year after the judgment, on March 8, 2006, Nichia officially announced the related would abandon all the rights of patent 404. Nichia decided to abcador not only patent 404, but all patents for the purpose of cost reduction in its business practice of patent management. In 2005, Nichia abandoned fifty patents, both national and international patents.

It was confirmed that the four counterpart firms, which Nichia had cross-licensed after 2002. Toyoda Gosei, Osram, and Lumileds, and Cree, in fact, were not using patent 404 in manufacturing blue LEDs, because, the total maintenance cost would be double or triple if they imitate the practices associated with patent 404. Therefore, as long as a cross-licensing agreement is reached, there is no surprise in patent abandonment except for some key patents.

8. Conclusions

Generally, managers are quite aggressive and prefer to take straight action in pressing matters such as patent infringement. However, it is a part of the strategy to consider whether to issue an infringement-warning letter. If the legal costs would exceed the damages, a firm would not file a patent infringement lawsuit [11]. This study examined the hypothesis 1 that the higher the frequency of patent filing, the higher the self-citation ratio in the patents filed for a period of time in which a firm generated inventions for technological strategy. Furthermore, it became clear from the follow-up research that the outliers in **Figure 2** may well be engaged in inventions for patent strategy. The primary factor in promoting inventions for patent strategy is to prepare for cross-licensing negotiations, whereas cross-licensing negotiations are normally carried out in secret. Moreover, this analysis

showed that the increase in the number of patents over a certain period is accompanied by an increase in the self-citation ratio.

US firms show a tendency to have both higher self-citation ratio and higher average number of citations than Japanese firms. The hypothesis 2 explains that the self-citation ratio increases in proportion to the number of average self-citation during a specific period. The higher the self-citation ratio, the higher the number of average self-citation for a period in which a firm generates inventions for patent strategy. This supports the hypothesis, that is, these sixteen firms are considered to be linkages mainly between self-citation ratio and average number of citations. The primary factor in promoting inventions for patent strategy is to prepare for cross-licensing negotiations, which are normally carried out in secret.

This tendency indicates that the internal capacity and resources of the firm impose severe constraints on inventions when development is accelerated. In the semiconductor industry, the internal resources were critical when the speed of innovation was high. In fact, Podolny J. M. and Stuart T. E. (1995) proved that R&D depended on the existing technological position in the accumulative and complicated semiconductor technology [12]. In such an industry, communication with other firms may influence performance relatively less than internal resources, as suggested by the RBV.

It's time to bring IP strategy out of the management plan. More to the point, we submit that any business strategy not build around intellectual property is no strategy at all. Without intellectual property protection, a business can have no sustainable advantage over its competitors. Without sustainable competitive advantage, the odds of developing and sustaining outstanding profit performance plummet. Without an expectation of outstanding profit performance, businesses have little incentive to invest in innovation. The objective is to show that a modern technological business needs to place licensing strategy close to the center of any strategic plan.

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