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The Nature of Inventive Activities: Evidence from a Data-Set of the Okouchi Prizes and a Comparison with the R&D 100 Awards

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Abstract

This paper conducts preliminary analysis on technological innovation by using prize and award data sets: the Okouchi Prizes and the R&D 100 Awards. It aims to outline longitudinal patterns of award-winning industries, organizational type, and inter-organizational collaboration. First, it shows that most awards in the 1960s were given in the area of electric appliances. The iron and steel industry was the second leading prize winner of the Okouchi Prizes. Meanwhile, the segment of transportation equipment, one of the Japan's leading industries, fared poorly. Looking at the R&D 100 Awards, this segment's presence has increased in Japan, while it has decreased in the U.S. since the 1970s. Lastly, the inter-organizational collaboration ratio was higher in Japan than in the U.S. until the 1980s. However, the U.S. showed an increase in the collaboration ratio starting in the 1980s, when the ratio dramatically dropped in Japan.

1. Introduction

This paper conducts preliminary analysis on technological innovation by using prize and award data sets. It aims to outline longitudinal patterns of award-winning industries, organizational type, and inter-organizational collaboration.

Despite the fact that technology is one of the indispensable factors that increases a firm's competitive advantages, the debate over how to measure technological innovation continues. Innovation has been regarded as a residual factor, which is not explained by its growth model, in the Solowian tradition (Solow, 1956). Total factor productivity is commonly used to assess innovation in national accounting. However, it does not capture technological innovation alone because the residual is not perfectly equal to technological innovation. Patents have been widely used to examine technological change in a certain area of technology or industry because patents provide important information such

as the names of inventors, the name and address of the assignee, technological classification, technological inventiveness, and application date. Using patent citations provides only an estimated quality of technology because some patents do not have any economic impact (Carpenter and Narin, 1983; Carpenter et al., 1981; Shankerman and Pakes, 1986). Furthermore, there are several disadvantages to using patents (Griliches, 1990). For instance, not all technologies can be patented. Firms do not necessarily patent all of their inventions. Patents differ greatly in their technological economic significance.

Thus, there is no single indicator of technological innovation. This paper explores the nature of inventive activities by scrutinizing the data set of Okouchi Prizes. Award, prize, and exhibition data are used in the analysis of technological innovation. Patents formally protect intellectual property rights. Prizes diffuse technological knowledge. Because the primary aim of prizes is not to provide pecuniary gain, applicants do not heavily consider the costs of research and development when applying for prizes. The certification of new technologies by judges through a prize system confers indirect monetary benefits. Since information on the prize is publicly announced, the announcement promotes advertising and generates potential user awareness. Usually firms begin to consider awards after patenting an invention because the award does not provide any exclusive right of technology. Patent and prize are not interchangeable but complementary because inventors can pursue patents and prizes concurrently.

Various institutions award a prize. For example, the Nobel Foundation is perhaps the most well-known prize-awarding institution. Governmental institutions award citizens for their excellent technological achievements. For instance, the U.S. Patent and Trademark Office awards the National Medal of Technology and Innovation (formerly known as the National Medal of Technology). Academic societies and professional associations also provide awards in areas of expertise. For example, IEEE (the Institute of Electrical and Electronics Engineers) provides different types of award programs in the field of electric and electronics engineering.

This paper investigates the awards given by the Okouchi Memorial Foundation to explore longitudinal analysis on innovation in Japan for two reasons. First, one of the advantages of using the Okouchi Prize lies in the fact that the Okouchi Memorial Foundation does not rule out any particular field of industry. Even though the Foundation focuses on manufacturing and process

innovation rather than product innovation, it does not exclude certain industries from award consideration. The Okouchi Memorial Foundation allows time-series analysis on innovations from different industrial areas. Second, the Okouchi Prize is well-known in manufacturing sectors in Japan. Competition for the award is fierce. Thus, the Okouchi Prize competition is regarded as a good opportunity for firms, government laboratories, and academic institutions to showcase the outcomes of their R&D. Nominated technology is judged by third party expertise. Therefore, awarded R&D represents a technological breakthrough. Since the Okouchi Memorial Foundation reports detailed descriptions of award-winning R&D projects, they are explored as a case study. However, there is no longitudinal analysis of any data-set of the Okouchi Prizes.

This paper also conducts some preliminary comparative analysis by using the R&D 100 data-set. The R&D 100 Awards are given by the magazine *R&D* to the top technology products of the year. Since the magazine is distributed mainly in the U.S., it represents the trend of technological innovation in that country. The R&D 100 Awards data-set has been used in the Economics of Innovation. Fontana et al. explored the R&D 100 data-set and showed that breakthrough inventions were more likely to emerge in “turbulent” Schumpeter Mark I contexts (Fontana et al., 2009). However, the data-set has not been used for international comparative purposes. Through the comparison, this paper explores the historical transition of award-winning organizational types, industrial classes, and collaborative R&D. Because there are differences between the Okouchi Prizes and the R&D 100 Awards in the host organization, aim, and coverage, the findings should be carefully interpreted. However, the preliminary findings reveal several important points in the trend of inventive activities in the U.S. and Japan. A number of new actors, such as governmental organization and academic institution, gradually increased involvement in inventive activities in the late 1970s in the U.S., while the presence of these actors has been more marginalized in Japan. Furthermore, the pattern of collaborative R&D in the U.S. and Japan began to differ in the 1980s.

2. Okouchi Prize and R&D 100

In celebration of Masatoshi Okouchi’s achievements, the Okouchi Memorial Foundation was established in 1954. Masatoshi Okouchi was a Japanese physicist and entrepreneur. He graduated from Tokyo Imperial University in 1903 and began his career as a scholar. He became a director of

Rikagaku Kenkyūjo, which is still one of the largest natural sciences research institutes in Japan. He promoted empowerment of research group leaders and tried to commercialize their research outcomes. In 1927, he established spin-off companies that used the institute's research outcomes for commercial applications. The Okouchi Memorial Foundation has awarded distinguished achievements every year since 1954.

The following table shows four categories of prizes awarded by the Okouchi Memorial Foundation. A prize medal is given for all of the award categories. Prize money is given for Memorial Award (1 million yen) and for Production Special Award (30 thousand yen) only.

Table 1: Okouchi Prize Categorization

Recipient	Award Category	Description
An individual or group of people (not more than five)	Memorial Award	Distinguished Achievement in Industrial Engineering and Great Contribution in Academics and Industrial Development
	Technological Award	Distinguished Achievement in Industry based on Invention in Industrial Engineering and Advanced Manufacturing Technology
Organization	Production Special Award	Distinguished Achievement in Industry Created by Industrial Engineering Research
	Production Award	Distinguished Achievement in Industry based on Invention in Industrial Engineering and Advanced Manufacturing Technology

Applicants must note (1) Background and Target of R&D, (2) R&D process, (3) Description of Technology and its Features (e.g., originality, academic quality, advantages over competing technologies, economic performance, social contribution, and potentials), and (4) Achievements (e.g., production, sales, and market share).

Applicants may nominate themselves. The application and nomination are judged by a committee composed of industry experts and university professors. The committee asks additional information, interviews candidates, and, in some instances, conducts on-site investigations.

These award and evaluation processes are quite similar to those of the R&D 100 Awards. The R&D 100 Awards was established by *R&D Magazine* in

1963. Like the Okouchi Prizes, the award is given to a group presenting a distinguished industrial achievement. The candidates are judged by the magazine's editor with the advice of third party experts. Applicants are self-nominated. Both of the awards evaluate industrial and economic performance as well as technological significance. The product needs to be on the market when it is nominated for the award.

However, there are three significant differences between the R&D 100 and Okouchi Prize. The first is related to national boundary. On the one hand, the R&D 100 is quite international, even though its journal is published only in the U.S.. In 1963, only U.S. firms could win the award. However, the R&D 100 Awards were opened to non-U.S. organizations in 1964. On the other hand, all of the Okouchi Memorial award winners are Japanese. Even though the committee does not rule out nomination of foreign R&D projects, Japanese firms dominate the Okouchi Memorial award. The second is the number of award-winning R&D projects. While R&D 100 awards literally 100 R&D projects every year, the Okouchi Memorial Foundation recognizes 10 R&D projects.

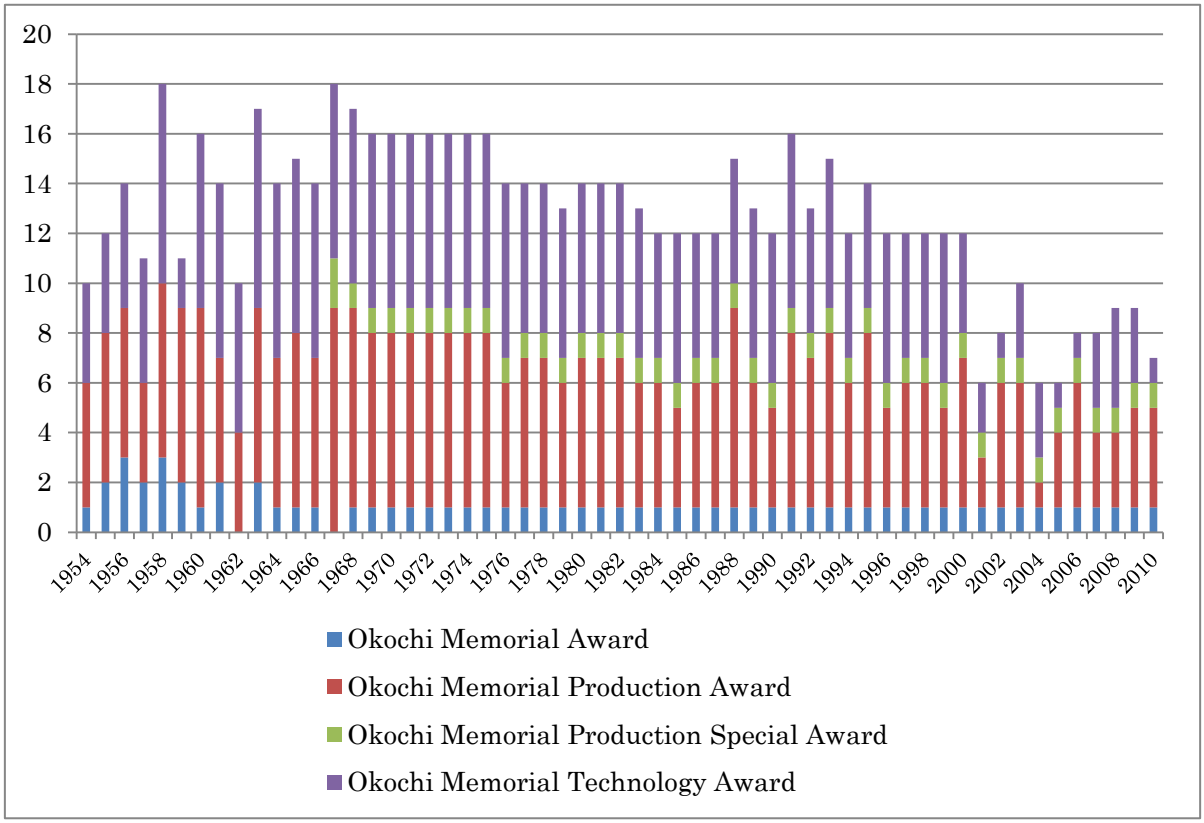
The last difference lies in the nature of invention. While both the R&D 100 Awards and the Okouchi Prizes do not rule out any particular technological area for consideration, their focuses are different. The Okouchi Prizes emphasize production technology. The R&D 100 Awards focus on a new product. In other words, while the R&D 100 Awards are based on product innovation, the Okouchi Prizes are awarded based on process innovation. Of course, this does not necessarily mean that product innovation is excluded from the Okouchi Prizes; some product innovation certainly originates from process innovation. Moreover, the award-winning process innovation exists in a marketable form such as patent licensing, manufacturing facility, and material. However, the focus of the Okouchi Prizes and the R&D 100 Awards is different as concerns the nature of technology.

3. Findings

The following figure shows the number of Okouchi Prizes awarded from 1954 to 2009. As it illustrates, ten to fifteen R&D projects have been awarded every year. The number of Memorial Awards has remained low. Since the Memorial Award is regarded as the best award, it has been given to only one R&D project; there were exceptions in 1956 and 1958, when the award¥ was given to two projects. The Special Production Award has been given to only one

R&D project.

Figure 1: Number of Awards



Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b, a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

By classifying award winning organizations based on Japan's securities identification code, Table 2 shows the distribution of the Okouchi Prize across industrial classes. If an award is given to multiple organizations, the figure takes the securities identification code of the principal organization appearing as the first author in the award report. If an organization is not listed and is not assigned a securities identification code, a code is assigned based upon the firm's business description and technological details as explained in the report. This table shows the decennial share of award-winning industrial classes from the 1950s to the 2000s.

Table 2: Award Winning Industrial Classes

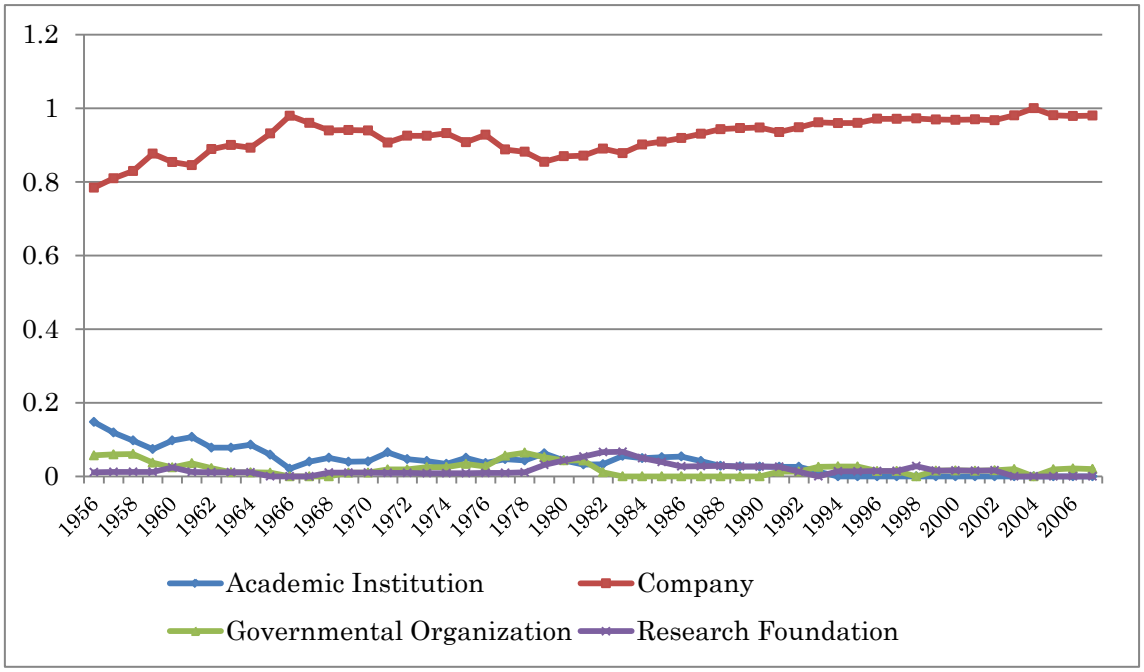
	1950	1960	1970	1980	1990	2000	Total
Electric Appliances	25.00	27.15	35.76	32.06	34.62	42.70	32.83
Iron and Steel	21.05	14.57	14.57	25.19	23.85	23.60	19.92
Chemical	9.21	21.19	19.87	14.50	10.00	7.87	14.84
Machinery	17.11	9.27	6.62	2.29	2.31	3.37	6.32
Transportation Equipment	2.63	5.30	5.96	9.16	7.69	4.49	6.18
Pharmaceutical	2.63	1.32	5.30	3.82	4.62	5.62	3.85
Textiles and Apparels	3.95	3.31	2.65	2.29	2.31	4.49	3.02
Nonferrous Metals	1.32	5.30	1.99	0.00	3.08	3.37	2.61
Precision Instrument	10.53	0.66	1.99	3.05	1.54	0.00	2.47
Glass and Ceramics	1.32	4.64	0.66	0.76	0.77	0.00	1.51
Foods	0.00	1.99	0.66	2.29	0.77	1.12	1.24
Information and Communication	0.00	1.32	0.00	2.29	2.31	0.00	1.10
Oil and Coal Products	0.00	0.66	0.66	0.00	1.54	1.12	0.69
Electric Power and Gas	1.32	0.00	1.99	0.00	0.00	1.12	0.69
Other Products	1.32	1.32	0.00	0.76	0.00	0.00	0.55
Pulp and Paper	1.32	0.00	0.66	1.53	0.00	0.00	0.55
Metal Products	0.00	1.99	0.00	0.00	0.77	0.00	0.55
Construction	1.32	0.00	0.00	0.00	2.31	0.00	0.55
Broadcasting	0.00	0.00	0.00	0.00	1.54	1.12	0.41
Land Transportation	0.00	0.00	0.66	0.00	0.00	0.00	0.14

Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b, a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

As Table 2 shows, the most represented industries are electric appliances, followed by chemicals and iron. The top three concentration ratio has been over 55 percentages throughout the time periods. It is interesting to note that despite Japan's competitive advantage in the automobile industry, the Okouchi Prize has rarely been awarded in the category of transportation equipment. This trend is also seen in R&D 100 as well.

Figure 2 displays the time series of award-winning organization categories. Award-winning organization is specified in the report on the award provided by Okouchi Memorial Foundation. If an award is given to multiple organizations, this figure gives a full count to the award winning organization. The figure shows that companies dominate the awards. This reflects the fact that production or its manufacturing process should exist in marketable form at the moment of the submission of the nomination. The domination by corporations is observed in the R&D 100 Awards as well (Figure 3). However, while the R&D 100 Awards shows this to be a declining trend, the reverse is true for the Okouchi Prizes. Data from the R&D 100 Awards suggest that a number of new actors such as governmental organization and academic institution gradually increased involvement in inventive activities in the late 1970s in the U.S. On the other hand, the presence of these actors is more marginalized in Japan.

Figure 2: Shares of Okouchi Prizes Granted to Different Types of Organizations[1]

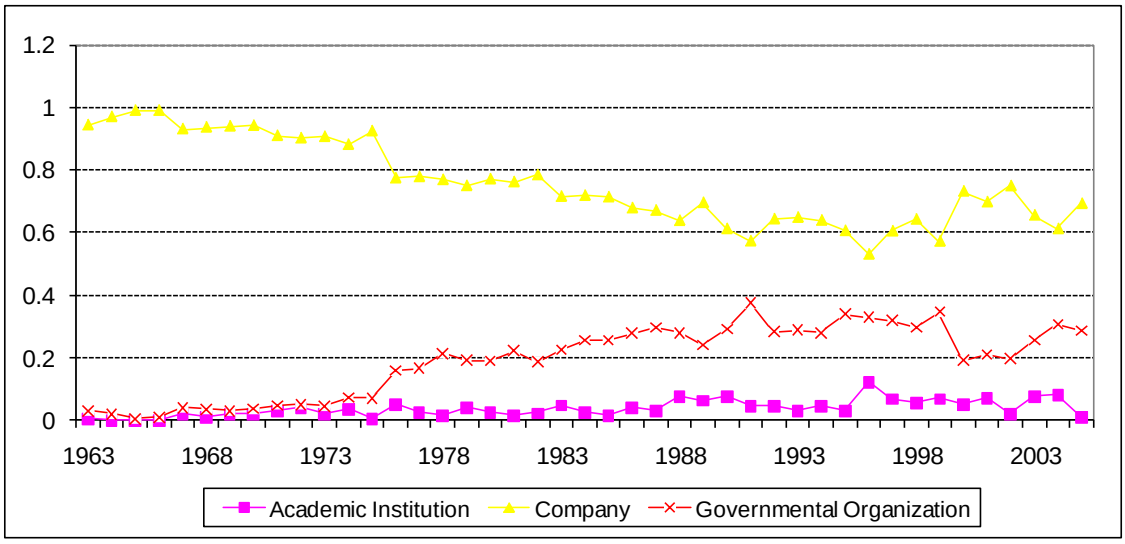


Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b, a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989,

[1] Nippon Telegraph and Telephone (NTT) was privatized in 1985. Therefore, technically, it was a nationally owned public corporation before 1985. However, the figure counts it as a company throughout the periods.

1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

Figure 3: Shares of R&D 100 Awards Granted to Different Types of Organizations



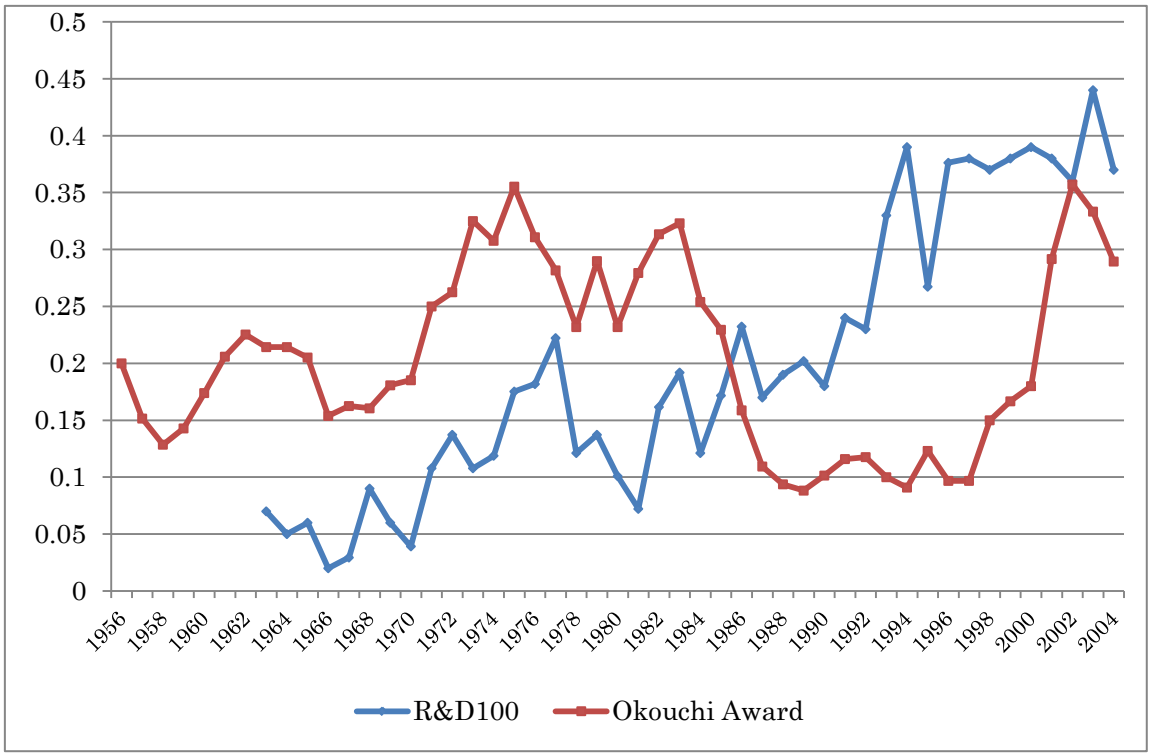
Source: extracted from (Fontana et al., 2009)

These trends suggest that the ways in which firms conduct their R&D and develop technological innovation in the U.S. and Japan may have diverged into different paths. Traditionally, in-house R&D has been an important source of innovation and competitive advantage for firms (Chandler et al., 2001; Mowery, 1983). However, with the increasing complexity of technology, it becomes impossible for firms to internalize all of the resources needed for in-house R&D (Powell et al., 1996). Thus, utilizing external information and resources gives firms an important competitive advantage (Chesbrough, 2003; Chesbrough et al., 2006; Freeman, 1991; Gulati, 1999). As the literature suggests, an increasing trend of collaborative inventive activity has been clearly observed in the R&D 100 Awards (Fontana et al., 2009).

The following figure shows the number of inter-organizational collaborations receiving an award from the R&D 100 Awards and the Okouchi Prize Committee. An inter-organizational collaboration is multiple organizations winning the prize as co-applicants and recipients. It is safe to hold this assumption because the Okouchi Prizes are given based on self-nomination.

Since the number of Okouchi Prize winning R&D projects hovers around 10 every year, the figure shows a five-year moving average of percentage of collaborative R&D for the Okouchi Prizes. Since the R&D 100 awards prizes to 100 R&D projects every year, the ratio of collaborating applicants receiving an R&D 100 award appears in the figure as annual collaboration ratio.

Figure 4: Inter-Organizational Collaborative R&D (Award Winning Year)



Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b, a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

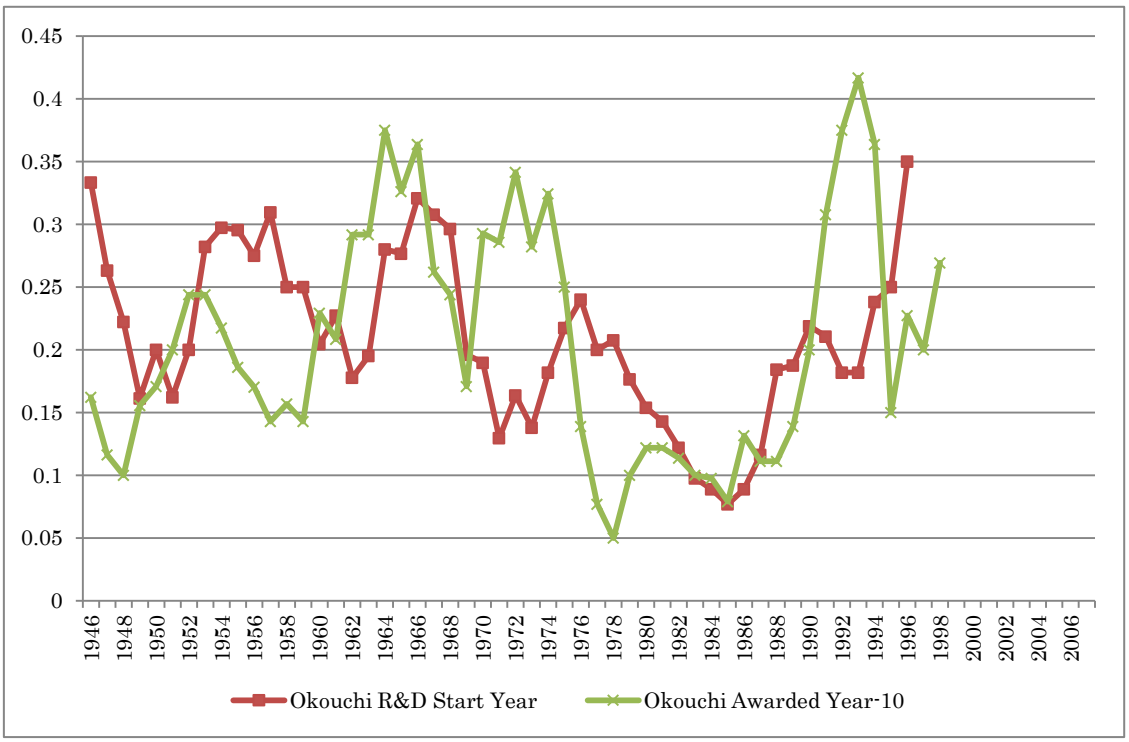
First, the figure illustrates the increasing trend of inter-organizational collaborations receiving an R&D 100 award after the 1960s. The inter-organizational collaboration was less than 10 percent in the 1960s. It sharply increased in the beginning of the 1990s and soon reached nearly 40 percent. Inter-organizational collaborative R&D began to increase in the 1980s because it takes a certain amount of time to complete and market an R&D

project. This trend is fully consistent with the emphasis that has been placed on the growing role of collaboration and networking in R&D. Since the share of the R&D 100 Award received by U.S. applicants has been not less than 82 percent throughout the period, it is reasonable to assume that this share represents the trend of collaboration in the U.S. Therefore, it suggests that the inter-organizational collaborative invention has been growing in the U.S. from at least the late 1980s, as many researchers have indicated (Chesbrough, 2003; Chesbrough et al., 2006; Hounshell, 1996).

Second, the ratio of inter-organizational collaborations receiving an Okouchi Prize reveals a different trend. Unlike the R&D 100, the Okouchi Prize trend does not show a linear increase. Rather, the figure fluctuated around 20-30 percent in the 1970s and 1980s. However, it dropped to around 10 percent from the middle of the 1980s until the beginning of the 2000s.

Third, one of the most striking observations is that the ratio of inter-organizational collaboration in the Okouchi Prize was greater than that of the R&D 100 Awards until the value dropped in the middle of the 1980s. This suggests that Japanese organizations, more so than U.S. organizations, traditionally utilize external resources. This is consistent with the previous literature indicating the close inter-firm relationships between Japanese suppliers and assemblers (Aoki, 1988; Asanuma, 1989; Clark and Fujimoto, 1991). However, in the 1970s, U.S. organizations gradually began to increase collaborations and to utilize external knowledge. The rate of U.S. collaboration soon overtook that of Japan in the middle of the 1980s, while the ratio of inter-organizational collaborative R&D sharply dropped in Japan.

Figure 5: Inter-Organizational Collaborative R&D (R&D Start Year)



Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b, a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

Based on the descriptions provided by the Okouchi Prizes report, Figure 5 shows the ratio of inter-organizational collaborative R&D based on its R&D start year. Because not all of the descriptions articulate R&D start year, Figure 5 also displays the award-winning year minus 10 years, which is the average period of time from the R&D start year to the award-winning year. This figure demonstrates that the declining share of inter-organizational collaborative R&D began in the late 1960s in Japan and continued until the early 1990s. Although it is necessary to conduct detailed investigation in order to better explain this downward trend, economic growth in the 1970s and 1980s might have influenced Japanese organizational R&D activity.

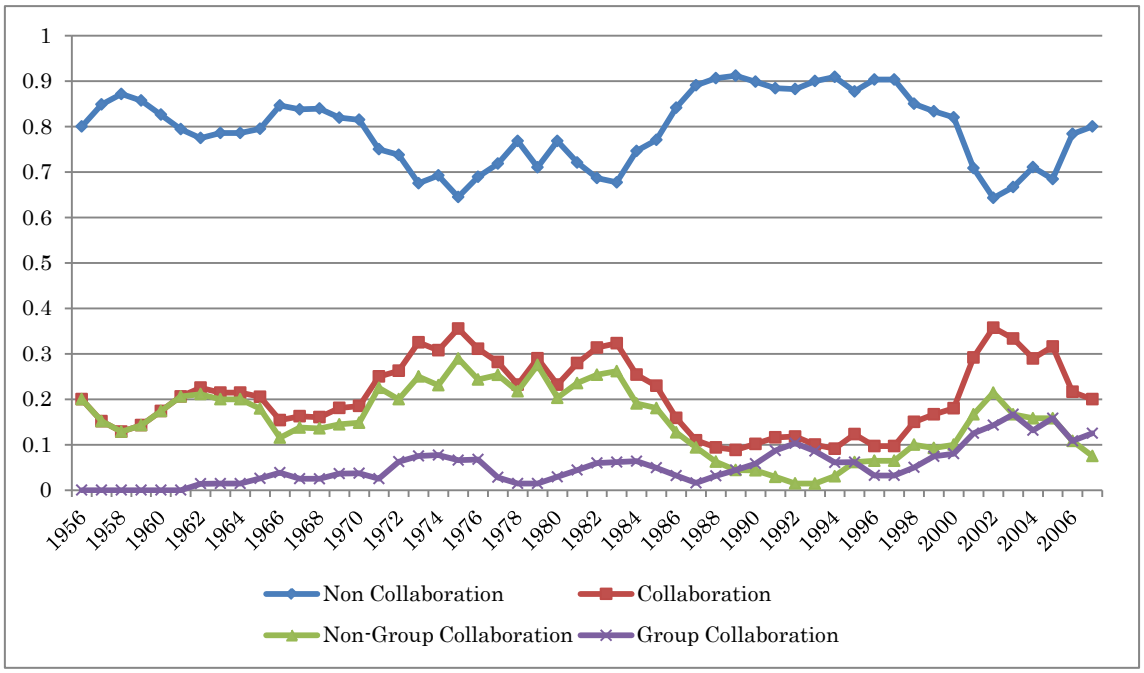
One might suppose that Japanese firms tended to collaborate among group-firms such as "*keiretsu*" or "*zaibatsu*" firms.[2] Actually, it is not rare to

[2] On "keiretsu" and "zaibatsu" see Miwa, Y., Ramseyer, J.M., 2006. The Fable of the

observe that inter-organizational collaboration among group firms won the prize. For example, Fujitsu won the prizes in 1981 and 1982 with Fujitsu Laboratories, which was separated from Fujitsu and became independent in 1968. Matsushita Electric Industrial and Matsushita Electronics won the prizes together in 1986. Hitachi shared the prize with Hitachi High-Technologies and Hitachi High-Tech Fielding in 2007. Denso shared the prize with Toyota Boshoku in 2001, both of which are Toyota Motor's important parts suppliers.

However, the number of award winning group-firm collaboration is not necessarily great, compared to the number of inter-organizational collaboration among non-group firms. The following figure shows the award winning year and the ratio of inter-organizational collaboration in the award winning R&D projects. It also takes five-year moving average. It illustrates that the group-firm collaboration is marginal except for the early 1990s when the ratio of collaboration was dropping. Thus, inter-organizational collaboration among group-firms is not a dominant collaborative pattern in the Okouchi Prize winners.

Figure 6: Collaboration in the Okouchi Prize Winners



Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b,

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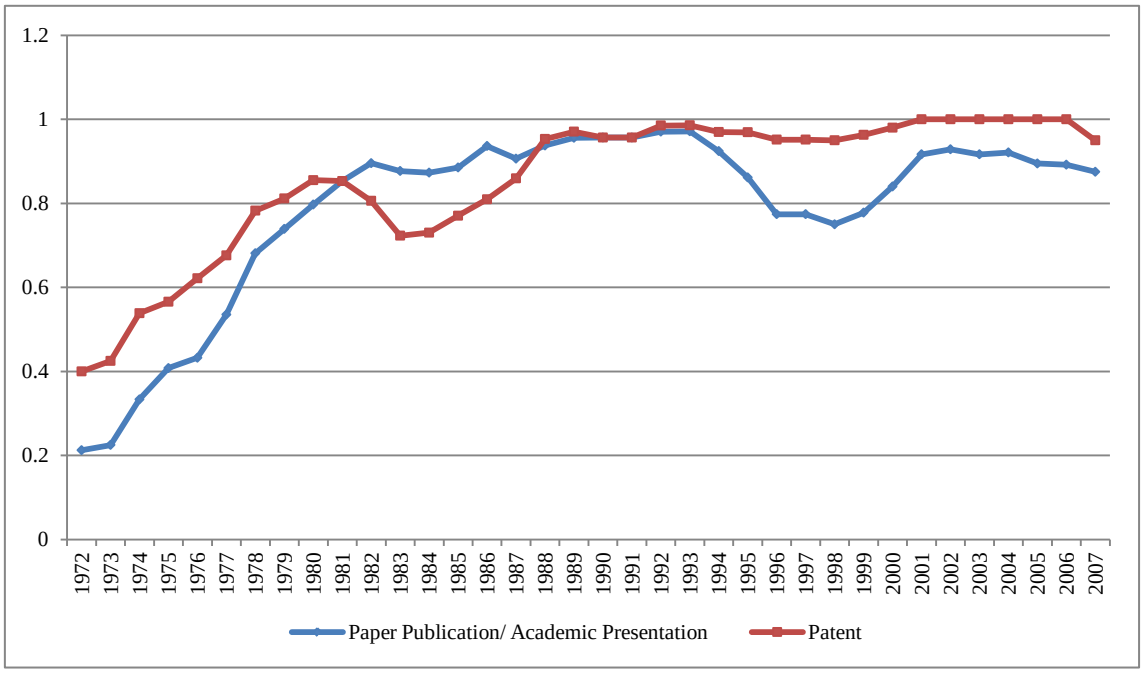
Keiretsu: Urban Legends of the Japanese Economy. University of Chicago Press ; [Bristol : University Presses Marketing, distributor], Chicago, Ill, Morikawa, H., 1992. Zaibatsu: the Rise and Fall of Family Enterprise Groups in Japan. University of Tokyo Press, Tokyo.

a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

Since the number of patents and paper publications are provided in the report on the award compiled by the Okouchi Memorial Foundation, we can explore how the award-winning inventions are related to academic community and how the inventions are patented. Because the R&D 100 Awards do not provide any information on patenting and academic relation, we cannot compare the trend of the Okouchi Prizes with that of the R&D 100. However, an interesting trend related to a role played by academic community can be seen if we take the marginal number of academic institutions in the Okouchi Prizes illustrated in Figure 4.

Figure 7 shows the ratio of award-winning R&D projects patented and presented in academic journals or at academic conferences. It takes a five-year moving average. Following the common format, the award-winning inventor provides descriptions on the invention, such as R&D target, technological details, R&D process, industrial performance, and patent/paper publications. However, this does not necessarily mean that the inventor perfectly follows the common format and provides all of the information. For example, some award-winning inventors report both patents that are already registered and patents that are being reviewed in the patent section, while other reports only registered patents. Some inventors report only the aggregated number of paper publications and academic presentations. Others provide them separately. Some provide an approximate number of patents or paper publications/academic presentations; others provide exact figures. Some winners may omit this section of the application entirely. Therefore, Figure 7 should be interpreted as the minimum percentage because it is self-reported by the award-winning inventors. In other words, the percentage could be greater, assuming we take the previous factors into consideration.

Figure 7: Patent and Paper Publications/Academic Presentations Ratio



Source:(Okouchi Memorial Foundation, 1974, 1975a, b, 1976a, b, c, 1977a, b, c, 1978a, b, c, 1979b, a, 1980c, b, a, 1981, 1982a, d, c, b, 1983b, a, 1984c, a, b, 1985, 1986, 1987a, b, c, 1988a, b, c, 1989, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011; Okouchi Memorial Foundation Tomonokai, 1960, 1962, 1964, 1967, 1968a, b, 1969a, b, 1970a, b, c, 1971, 1972a, c, b, d, 1973a, b, c, 1974a, b, c)

Figure 7 shows that the ratio of patenting began increasing in the 1970s and then plateaued at almost 100 percent. Without further investigation, we cannot tell if the patenting ratio actually increased or if the ratio of award winners reporting patents increased. However, it is assured that almost all award-winning R&D projects from the late 1980s and on were patented. Figure 7 suggests that the role played by the academic community is increasing as well. Even though the number of academic institutions receiving the award is marginal, the increasing ratio suggests that the inventive activity has become more science-based. This pattern is consistent with the previous study indicating the growing importance of academic institutions (Cockburn and Henderson, 1998; Fabrizio, 2006; Zucker et al., 2002).[3]

[3] Because the R&D 100 Awards data do not allow investigating a role in inventive activity played by academic community, we cannot make any comparison between the Okouchi Award and the R&D 100.

4. Conclusions

Patent data have been thoroughly examined in the economics of innovation. However, prize and award data have not been adequately explored. The Okouchi Prizes data-set has not been used in the time-series analysis of technological innovation, even though each award-winning invention has been analyzed as a case study. Thus, by examining the Okouchi Prizes in comparison with the R&D 100 Awards, we could explore the longitudinal trend of technological innovation in this preliminary comparative analysis. It must be noted that the trends observed in the Okouchi Prizes do not necessarily reflect general R&D trends of Japanese firms. Technically, the Okouchi Prizes data set shows not the general trend of Japanese firms but the trend of award-winning R&D projects.

Three main findings are summarized as follows. First, electric appliances became the most award-winning sector in the 1960s. The iron and steel industry is the second leading area in the Okouchi Prizes. The presence of transportation equipment, which has been one of the Japan's leading industries, has been minimal.

Second, company dominance has been increasing in Japan, but decreasing in the U.S. since the 1970s. Moreover, the difference in the inter-organizational collaboration R&D ratio is interesting. The inter-organizational collaboration ratio was higher in Japan than in the U.S. until the 1980s. However, the U.S. showed an increase in the collaboration ratio in the 1980s, while the ratio dramatically dropped in Japan.

Lastly, this paper explores the patent and paper publication/academic conference presentation ratio. It is interesting to observe that the paper publication/academic conference ratio increased over time, even though the number of academic institutes receiving the award remained minimal. This suggests that the inventive activity became more science-based and the relationship with academic community became more important, even though Japanese firms' collaboration with academic institution remained quite marginal in the Okouchi Prize.

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