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Patent statistics: deciphering a ‘real’ versus a ‘pseudo’ proxy of innovation

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Abstract

Patent statistics have fascinated economists concerned about innovation for a long time. However, fundamental questions remain as to whether or not patent statistics represent the real state of innovation. As Griliches pointed out, substantial questions involve: What aspects of economic activities do patent statistics actually capture? And, what would we like them to measure? He pointed out that these statistics can be a mirage appearing to provide a great number of objective and reliable proxies for innovation.

This paper aims to address some of these questions by making a comparative evaluation of the representability of patent statistics in four levels of the innovation process, using as examples research and development (R&D) in Japan’s printer and photovoltaic solar cell (PV) industries over the last two decades. Furthermore, this research provides a new set of patent statistics which could be considered a more reliable proxy for innovation. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Patent statistics; US Foreign Priority Patents; Pseudo proxy of innovation; Patentometrics

1. Introduction

Patent statistics have fascinated economists concerned about innovation for a long time (Anon, 1981). However, fundamental questions remain as to whether or not patent statistics represent the real state of innovation. As Griliches (1998) pointed out, substantial questions involve: What aspects of economic activities do patent statistics actually capture? And, what would we like them to measure? He pointed out that these statistics can be a mirage appearing to provide a great number of objective and reliable proxies for innovation.

Many papers have attempted to answer these fundamental questions.[1] However, they leave much unanswered in terms of generality and objectivity.

Patent data provide important information supportive to techno-economic analysis derivable from patent documents which encompass the geographic distribution of particular inventions, citation networks and patterns, as well as a detailed text of a series of patents in a particular field representing the raw material for a techno-economic history of particular areas. The information implicit in patent counts, in the number of patents issued at different times, in different countries, and to different types of inventors also contains important information supportive to techno-economic analysis (Griliches, 1984, 1998). This is the main topic of this paper.

Soete (1978) and Pavitt (1983) examined the relationship between investment in research and development (R&D) and the number of patents at the national level, and proved statistically that there exists a significant relationship between them. However, their correlation analyses are not reliable due to the inconsistency between patent statistics and R&D investment, as their patent statistics include applications by foreign firms while R&D investment does not include investment by foreign firms.

As demonstrated by many scholars (e.g., Pavitt, 1980,

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[1] Griliches (1998) referred the following three groups as noteworthy modern ‘computer age’ work: (1) NBER group (Griliches, Hall, Hausman, Jaffe, Pakes, Schankerman, and others), (2) Scherer and the Yale group (Levin, Nelson, Klevoric, Winter, Reiss, Cohen, and others), and (3) SPRU group (Freeman, Pavitt, Soete, and others).

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1985; Basberg, 1987; Griliches, 1990; Archibugi, 1992), greater numbers of patents are first applied to home countries (the so-called home country advantage) and then to foreign countries with potential market prospects.

Soete and Wayatt (1983) analyzed the correlation between the R&D investment of OECD member countries and their patent applications in foreign countries in the latter half of the 1970s, and proved a statistically significant correlation between the two variables (see also Soete, 1980). On the basis of these results they postulated that patent applications to foreign countries, not the home country, provide a better demonstration of innovation for each of the respective countries. They postulated that, among patent applications applied to foreign countries, applications to the USA provide strong representability of innovation since the number of patent applications to the USA is proportional to the extent of innovation.

Schiffel and Kitti (1978) postulated a different view by demonstrating that the export value to the USA has a stronger correlation with patents applied to the home country rather than to the USA (see also Marmor, 1979). Slama (1981) and Evenson (1984) supported this postulate by demonstrating that those countries adjacent to the USA have a higher registration ratio to the US Patent and Trademark Office (USPTO: hereinafter called the US Patent Office) than other countries. Similar support was also made by Pinson (1982) who demonstrated that, among the numbers of patent applications made to the USA by other countries, the number from Canada is 37% higher than from other countries and this is simply due to the short distance between the two countries. In addition, Basberg (1987) examined Norwegian patent applications to the USA by industrial sectors and proved that there was no significant correlation with Norwegian export to the USA.

Following these discussions, Faust (1990) pointed out that a thorough examination is indispensable for international comparison by means of patent statistics and proposed an idea of the ‘patent family’ as a practical method for thorough examination. Although this approach provides a practical method for examining a great number of patents in a practical way, this method contains substantial constraints as it depends on a classification by proximity which is subjective to the examiners.

Grupp and Schmooh (1999) reviewed patents in the USA and Europe, as well as the patent family, for reliable patent indicators for international comparative analysis, and postulated the idea of the ‘triad patent’. A triad patent is common to two out of the three areas of North America, Europe and Japan. They postulated that the triad patent represents real innovation more than single patents since it reflects geographical and trade conditions. They made a comparative evaluation of various patent indicators including the triad patent by making a correlation analyses with an export share of 17 leading countries, and demonstrated that the triad patent provides statistically more significant results in many of the countries examined. However, the correlation analysis in the case of Japan did not prove statistical significance as Japan’s patent number is exceptionally large. Furthermore, it is still unproven whether or not a correlation between the triad patent, export share and innovation has logical meaning.

While patent statistics provide supportive information for techno-economic analysis, a reliable patent indicator representing the real state of innovation that is practically applicable to techno-economic analysis and understanding the role of these statistics are still evolving. Thus, the questions posed by Griliches remain unsolved.

This paper aims to address some of these issues by making a comparative evaluation of the representability of patent statistics in four levels of the innovation process, using as examples Japan’s printer and PV R&D over the last two decades. Furthermore, this research provides a new set of patent statistics which could be considered a more reliable proxy for innovation.

Section 2 reviews the state of the existing tera-structure of patent statistics. Section 3 conducts a comparative evaluation of these tera-statistics. Section 4 presents an interpretation of the results of this comparative evaluation. Finally, Section 5 briefly summarizes the implications of this analysis.

2. State of tetra-structure of patent statistics

R&D activities generate innovations. Innovators generally protect their intellectual assets as an innovator, usually by patent. In light of this general behavior, patent statistics have fascinated economists concerned about innovation. Consequently, patent statistics have been used as a proxy of innovation.

Patent statistics encompass a multi-structured process facilitating patent applications to recognized legal authorities by innovators and firms according to business strategies. Fig. 1 illustrates this structure. In Japanese firms this structure can be characterized as a tetra-structure consisting of (1) the whole innovation, (2) the innovation as applied to the Japan Patent Office (JPA), (3) the innovation as registered in the Japan Patent Office (JPR), and (4) the innovation registered in the US Patent Office (USR). In addition to the above four clusters, we have identified the significance of the US Foreign Priority Patents (UFP), which are homogeneous to the USR, but these applications are not sent through to the US Patent Office for various reasons. Even though the quality of innovation reflected in the applications is the same as that in the USR, many firms do not apply to the US Patent Office the same volume of application as to the Japan Patent Office because of cost constraints and firm

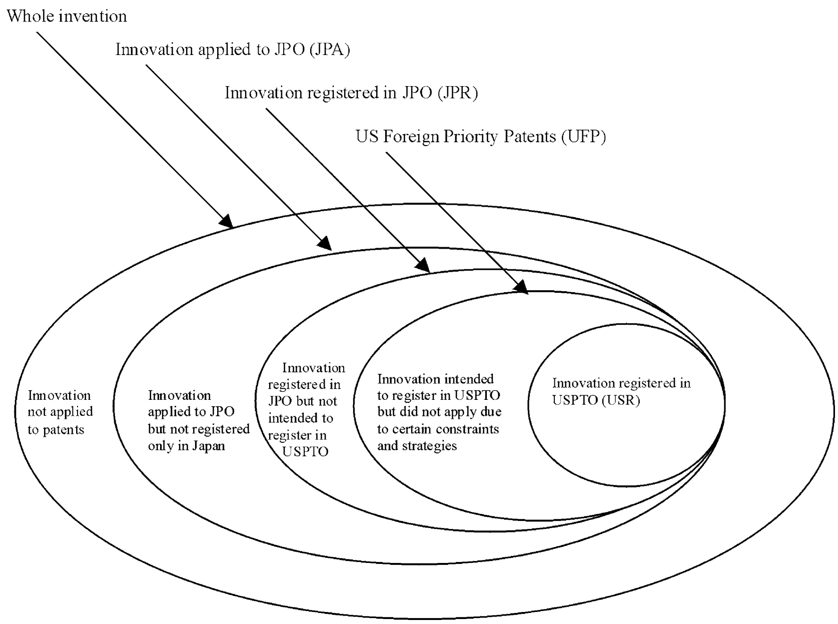

Fig. 1. Tetra-structure of Japaneses firms' patent application/registration [JPO: Japanese Patent Office; USTPO: US Patents and Trademarks Office (US Patent Office)].

market strategy. For Japanese firms, application to the US Patent Office is extremely expensive and complicated.[2] Therefore, many qualified innovations developed by small and medium enterprises (SMEs) are not registered with the US Patent Office. Japanese firms with certain strategies in Europe are not necessarily active for registration with the US Patent Office. For these reasons a certain number of qualified innovations fall into the gap between the USR and UFP. Among these four statistics, the US Foreign Priority Patent (UFP) is considered to be the best proxy for the real state of innovation because innovation applied or registered in the Japan Patent Office contains pseudo innovation including decoys and defenses against competitors. Japanese firms apply for their patent in the US Patent Office in a very selective way and do not include applications for decoys but only innovation really worthwhile registering in this process (Pavitt, 1983). In this context, innovation registered in the US Patent Office (USR) has been popularly used as a proxy for innovation (Soete and Wayatt, 1983). However, it does not contain important innovation, the quality of which is similar to that found in the USR but not registered for the reasons outlined above.[3]

3. Comparative evaluation of tera-statistics

In order to demonstrate this hypothetical view, comparative evaluations of the representability of four patent statistics for the innovation process typical of Japan's high-tech R&D were conducted. The businesses evaluated were Canon's (Canon Inc.) printer R&D over the period 1979–1997 and Sanyo's (Sanyo Electric Co.) photovoltaic (PV) solar cell R&D over the period 1980–1996.[4]

R&D expenditure (R) and the resulting technology stock (T) are the sources of innovation for printer and PV technologies, respectively. Consequently, this R&D expenditure and subsequent technology stock would generate a number of patents in the fields of printers and PVs. This work is in line with previous methodological approaches (such as Griliches, 1990) in providing that the generation of these patents is governed by the flow and stock of respective R&D, and they are represented by the respective R&D expenditure and technology stock of the respective R&D.

The number of respective patents (PAT) can be represented by the following equation:

$$PAT = F_1(T, R). \quad (1)$$

Given that the essential requirement of the patent

[2] While the application fee of each patent to the Japan Patent Office is ¥300–400 thousand, the similar fee to apply to the US Patent Office is ¥2000–2500 thousand.

[3] See Appendix A and Fig. 2 for trends in the discrepancies between the four statistics in Japan's high-technology R&D.

[4] Canon Inc. is one of the world's top producers of printers and their sales share out of Canon's total sales amounts to 50%. Currently, Japan is the world's top producer of PV cells and Sanyo Electric Co. is among Japan's top three producers of PV cells.

application is the novelty of a new idea and this novel idea generally is depleted as time passes (Griliches, 1990; Watanabe et al., 2000), a third factor *t* that represents the time trend should be incorporated in the equation for the number of patents as follows:

$$PAT = F_2(t, T, R). \quad (2)$$

Based on Eq. (2) and using four patent statistics for the innovation process of the respective R&D, comparative evaluations were conducted. Considering the certain time-lag between the emergence of a novel idea generated by *t*, *T* and *R*, and patent application and registration, the following time-lags are imposed to *T* and *R* in the right-hand side of Eq. (2) corresponding to the 'submarine period' and the examination period for patent registration indigenous to the respective patent statistics:[5]

JPA — 1 year;
JPR — 5 years;
USR — 2 years; and
UFP — 0 year.

Fig. 2 illustrates trends in patent application/registration within the tetra-structure of Canon's printer R&D.[6] Fig. 2 demonstrates a clear discrepancy between the four statistics. The discrepancy between JPA and JPR encompasses innovation rejected by the Japan Patent Office for registration or withdrawn by the applicants after application. The discrepancy between JPR and UFP encompasses patents registered in the Japan Patent Office for, primarily, defensive and decoy purposes. The discrepancy between UFP and USR encompasses qualified innovations worthwhile registering at the US Patent Office but not registered because of economic constraints or firms' geographical trade strategies. Looking at Fig. 2 we note that although the general trends in the numbers of the four statistics are similar, there exists a large discrepancy between JPA and JPR as well as between UFP and USR. While the former discrepancy is generally pointed out and understood, the latter discrepancy is rather surprising. This discrepancy implies that a certain number of important innovations, the quality of which are equivalent to the USR, are missing from USR statistics.

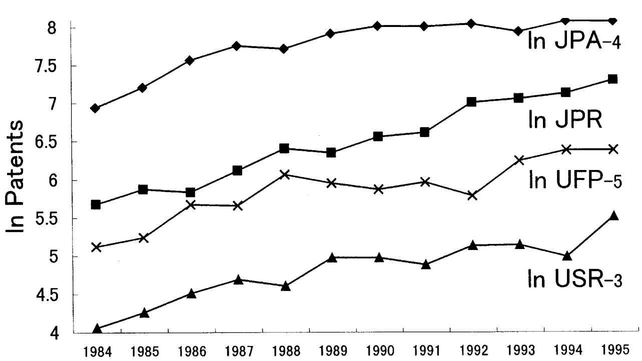

Fig. 2. Trends in patent application/registration in tetra-structure of Canon's printer R&D (1984–1995). JPA_{-4} indicates JPA with 4-year time lag; UFP_{-5} indicates UFP with 5-year time lag; and USR_{-3} indicates USR with 3-year time lag.

Tables 1 and 2 summarize results of the evaluations using regression analyses based on a simple Cobb–Douglas type of equation [Eq. (2)]. While all factors in the right-hand side of Eq. (2) (*t*, *T* and *R*) demonstrate a significant contribution to patents in all four statistics in printer R&D, *t* and *T* demonstrate a significant contribution to patents in all four statistics in PV R&D. This is due to the strong path-dependent nature of PV innovation resulting in a strong dependency on the accumulation of R&D rather than the flow of R&D. Tables 1 and 2 demonstrate that UFP proves statistically extremely significant compared with the other three statistics in both Canon's printer R&D and Sanyo's solar cell PV R&D. In the case of Canon's printer R&D, the coefficient of technology stock (α) is extremely high and statistically more significant than in the other three statistics. The coefficient of R&D expenditure (β), although not so conspicuous as technology stock, demonstrates similar significance. The coefficient of yearly decay (λ) provides a high negative value which demonstrates that active patenting activities were emerging in UFP of Canon's printer R&D (Tsuji, 2001). Contrary to UFP, all coefficients of USR are demonstrated to be less active. Thus, as far as assessing the level of coefficients and statistical significance, UFP demonstrates a high representability of the active innovation typically observed in Canon's printer R&D. A similar observation can be made in the case of Sanyo's PV solar cell R&D.

4. Interpretation

Comparing trends in the four statistics for the same level of innovation, similar trends with a parallel path were observed. However, certain discrepancies exist between the four statistics. Importantly, these discrepancies between JPA and JPR as well as between UFP and USR are significant. These observations suggest that there exists a certain structural impediment between

[5] JPA: an 18 month period when applications are acted on by the Patent Office out of turn in preference to others pending in the same class (1 year time-lag is imposed); JPR: 1 year for JPA plus 4 years for JPO's examination (Annual Report of JPO, JPO, Tokyo, annual issues); USR: 1 year for JPA plus 1 year for USPTO's examination; UFP: no time-lag as UFP refers to the latest R&D activities.

[6] In order to compare the four statistics at the same status of innovation, the following time lags are put on JPA, USR and UFP, using JPR as standard: JPA — 5−1 = 4 years; JPR — 0 year; USR — 5−2 = 3 years; and UFP — 5−0 = 5 years.

Table 1
Comparative evaluation of the representability of four patent statistics in Canon's printer R&D (1979–1997). Model[a]: $\ln Patent = a+\lambda t+\alpha \ln T+\beta \ln R$

Patent[b]	λ	α	β	adj. R^2	DW	Time lag of T and R (years)[c]
UFP[d]	−3.29	16.03	1.90	0.945	1.77	0
	(−15.16)	(13.22)	(4.46)			
USR	−0.25	1.65	0.34	0.969	2.26	2
	(−1.29)	(1.61)	(1.42)			
JPA	−0.52	2.69	0.52	0.905	1.79	1
	(−3.06)	(2.97)	(1.97)			
JPR	−0.42	2.05	1.01	0.976	2.14	5
	(−2.43)	(3.09)	(2.88)			

[a] t = time trend; R = R&D expenditure (fixed prices); and T = technology stock.
[b] Patents encompass IPC codes B41J+G03G.
[c] Technology stock at time t is given by: $T_t = R_{t-m}+(1-p)T_{t-1}$, where m = time lag between R&D and commercialization and ρ = rate of obsolescence of technology. Based on an empirical analysis on Canon's LLBP, LBP and BJ printers, the following identification was made: m = 4.0 years and ρ = 6.7% (lifetime is 15 years).
[d] UFP demonstrates a similar strong statistical significance over the period 1979–1995 (the period excluding 1996 and 1997 when UFP statistics are tentative) as follows: $\lambda = -1.73$ (−14.14); α = 7.84 (12.29); β = 1.92 (13.17); adj. R^2 = 0.962; DW-2.05; time lag of T and R = 0 year.

Table 2
Comparative evaluation of the representability of four patent statistics in Sanyo's solar cell PV R&D (1980–1996). Model[a]: $\ln Patent = a+\lambda t+\alpha \ln T$

Patent[b]	λ	α	adj. R^2	DW	Time lag of T and R (years)[c]
UFP	−0.50	3.56	0.940	2.62	0
	(−10.64)	(12.89)			
USR	−0.34	3.15	0.910	1.70	2
	(−3.04)	(5.00)			
JPA	−0.12	1.10	0.958	2.04	1
	(−3.90)	(6.23)			
JPR[d]	−0.14	1.44	0.960	1.62	5
	(−2.32)	(4.65)			

[a] t = time trend; R = R&D expenditure (fixed prices); and T = technology stock.
[b] Patents encompass IPC code HO1L.
[c] Technology stock at time t is given by: $T_t = R_{t-m}+(1-p)T_{t-1}$, where m = time lag between R&D and commercialization and ρ = rate of obsolescence of technology. Based on a questionnaire for 19 Japanese leading PV firms (1993), the following identification was made: m = 2.8 years and ρ = 20.3% (lifetime is 4.9 years).
[d] Due to data availability, the period of analysis for JPR is 1983–1998.

these statistics. While the discrepancy between JPA and JPR has been generally pointed out and appears rather natural, the discrepancy between UFP and USR should be taken seriously. This implies that USR statistics, which have been popularly used as a reliable proxy of innovation, contain a certain 'missing link'. Furthermore, this is not temporary but structural and the amount is not necessarily a negligible one. Empirical observations demonstrate that this 'missing link' contains many important innovations of a quality that is equivalent to the USR. As a matter of fact, although Canon and Sanyo are active in applying for their patents at the US Patent Office, they also apply for their patents in selective ways and they have some innovations for which they are primarily focusing on markets other than the USA. These facts result in the reality that the USR does not represent their entire innovative activities and, in fact, a higher representability of their entire innovation is actually seen in the UFP.

A comparative numerical analysis proves these empirical observations. A regression analysis between R&D input (R&D expenditure and its resulting technology stock) and UFP demonstrates an extremely strong statistical significance beyond the other three statistics. Canon's printer R&D as well as Sanyo's PV R&D are considered some of the most competitive high-technology businesses, compelling them to perform intensive R&D and leading to active patenting activities. Contrary to the results of regression analyses using USR, UFP demonstrates statistical significance reflecting these active innovative activities typically observed in Canon's printer R&D and Sanyo's PV R&D.

On the basis of the above analyses, UFP can be considered to yield reliable statistics representing the real state of innovation in Japan's high-technology firms.

5. Implications

On the basis of intensive empirical observations on various patent statistics, this paper first identified a 'missing link' that has not been encompassed in innovations registered in the US Patent Office (USR) in an attempt to address fundamental questions regarding whether or not patent statistics represent the real state of innovation.

This identification has led to the postulation of a new set of patent statistics by counting the above 'missing link' from the US Foreign Priority Patents (UFP).

Through comparative evaluation between various patent statistics including UFP, using a regression analysis between patent statistics and R&D activities for innovation, contrary to the popularly used USR statistics (innovation registered to the US Patent Office), UFP was proved to be extremely reliable with high representability of innovation. Thus, UFP statistics have been postulated as a more reliable proxy of innovation, at least in Japan.

The advantage of UFP is that it includes statistics filtered by the US Patent Office examination for its registration, which is currently becoming a global standard. Thereby, the UFP could be developed as a practical proxy of innovation useful for international comparison. In addition, a similar attempt could be developed in patent applications in Europe by utilizing EU Foreign Priority Patents (EFP). Further investigations in this direction, together with further development of case demonstration, should be undertaken immediately to further understand the use and significance of UFP statistics.

Appendix A. Data construction and sources

A.1. R&D expenditure (R: 1990 fixed prices)

1. Canon's printers:
   [Canon's average R&D expenditure per researcher][7]×[Number of researchers involved in printer R&D][8] elaborated by interviews (see Watanabe et al., 2001).

[7] Estimated by the Canon Story (Canon Inc., Tokyo, annual issues).

[8] Estimated by the Canon Story: 50 Years of Technology and Products (Canon Inc., Tokyo, 1987).

2. Sanyo's PVs:
   Questionnaire for 19 leading PV firms (conducted in 1993 under the support of AIST of MITI) and supplemented by interviews (see Watanabe et al., 2000).
3. Deflated by R&D deflator (White Paper on Science and Technology, Science and Technology Agency, Tokyo, annual issues).

A.2. Technology stock (T: 1990 fixed prices)

$$T_t = R_{t-m}+(1-\rho)T_{t-1},$$

where m is the time lag between R&D and commercialization; ρ is the rate of obsolescence of technology).

	m	ρ	Source
Canon	4.0 years	6.7% (lifetime = 15 years)	Canon's printer development program
Sanyo	2.8 years	20.3% (lifetime = 4.9 years)	Questionnaire for 19 leading PV firms (see above).

Estimated m and ρ have been proved to be statistically significant (see Watanabe and Griffy-Brown, 2000).

A.3. Patent statistics

A.3.1. JPA and JPR

1. Canon's printers:
   Data extraction using PATOLIS (JAPIO): Canon∗(B41J+G03G)∗19xx
2. Sanyo's PVs:
   Data extraction using PATOLIS (JAPIO): Sanyo Electric∗H01L∗19xx

A.3.2. USR

Data extraction using Boolean Search (Patent Bibliographic and Abstract Database, available at http://www.uspto.gov/):

Canon∗intnl. Class = (B41J+G03G)∗19xx
Sanyo Electric∗intnl. Class = H01L∗19xx

A.3.3. UFP

Collected original patent application codes from Foreign Application Priority Data in the above database

Table 3
R&D and patent statistics[a] on Canon's printer R&D (1979–1997)

Year	RPR	TPR	JPAPR	JPRPR	USRPR	UFPPR
1979	2.0	3.8	755	146	29	168
1980	2.2	4.8	1033	258	36	189
1981	2.4	5.9	1347	250	58	291
1982	3.0	7.3	1926	183	71	288
1983	3.9	8.8	2329	200	91	431
1984	5.1	10.4	2239	293	109	385
1985	6.5	12.1	2725	357	100	355
1986	7.6	14.4	3010	343	145	390
1987	8.5	17.3	2993	454	145	327
1988	10.6	21.2	3098	604	132	515
1989	12.1	26.3	2797	571	170	590
1990	13.5	32.1	3210	703	171	592
1991	15.1	38.5	3199	743	147	560
1992	16.0	46.5	3872	1104	249	474
1993	17.1	55.5	2835	1162	263	436
1994	20.6	65.3	3099	1249	237	318
1995	22.5	76.0	3459	1483	258	225
1996	27.6	86.9	3915	1412	407	57*
1997	31.4	98.2	3551	1381	343	10*

[a] RPR: Canon's R&D expenditure on printer R&D (100 million yen at 1990 fixed prices); TPR: Canon's technology stock on printer R&D (100 million yen at 1990 fixed prices); JPAPR: Canon's printer innovations applied to the Japan Patent Office; JPRPR: Canon's printer innovations registered in the Japan Patent Office; USRRPR: Canon's printer innovations registered in the US Patent Office; UFRPR: Canon's printer US Foreign Priority Patents (* indicates tentative figure).

Table 4
R&D and patent statistics[a] on Sanyo's PV R&D (1980–1996)

Year	RPV	TPV	JPAPV	JPRPV	USRPV	UFPPV
1980	4.9	6.8	87	39	1	3
1981	7.0	7.5	84	40	1	4
1982	6.8	8.2	137	46	1	4
1983	8.9	11.4	172	46	1	5
1984	11.0	16.1	247	44	0	20
1985	11.7	19.7	239	43	4	15
1986	15.3	24.6	380	47	8	15
1987	15.8	30.7	394	56	9	27
1988	16.2	36.3	400	37	8	30
1989	16.0	44.3	404	44	13	46
1990	16.0	51.3	428	55	4	22
1991	17.7	57.2	449	72	10	23
1992	18.5	61.8	454	121	14	29
1993	21.5	65.4	429	181	25	32
1994	20.5	70.0	423	239	9	23
1995	19.5	74.5	404	286	12	12
1996	21.2	81.2	423	234	17	5

[a] RPV: Sanyo's R&D expenditure on PV R&D (billion yen at 1990 fixed prices); TPV: Sanyo's technology stock on PV R&D (billion yen at 1990 fixed prices); JPAPV: Sanyo's PV innovations applied to the Japan Patent Office; JPRPV: Sanyo's PV innovations registered in the Japan Patent Office; USRRPV: Sanyo's PV innovations registered in the US Patent Office; UFRPV: Sanyo's PV US Foreign Priority Patents.

and compiled numbers of the codes in a consistent way by eliminating overlaps.

A.4. Outcome of measurement

Tabulated outcome of measurement is summarized in Tables A1 and A2.

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