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Technological diversification and assimilation of spillover technology: Canon's scenario for sustainable growth

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Abstract

Under the paradigm shift from an industrial society to an information society in the 1990s, contrary to the decrease of profits in Japan's electrical machinery firms, only Canon demonstrated its increasing trend. This contrasting performance corresponds to Canon's another contrast with respect to increasing technological diversification while reverse trends in other electrical machinery firms. These contrasts suggest us that Canon's technological diversification strategy can be the source of high level of its profits.

Prompted by this hypothetical view, this paper analyzes Canon's scenario for sustainable growth and attempts to elucidate its technological diversification dynamism with special attention to its contribution to high level of profits. On the basis of the identification of the correlation between technological diversification and assimilation of spillover technology, comparative empirical analyses are conducted focusing on the consequence of technological diversification and development trajectory in Japan's leading electrical machinery firms over the last two decades.

Keywords: Technological diversification; Assimilation of spillover technology; Operating income to sales; Canon

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1. Introduction

Under the paradigm shift from an industrial society to an information society in the 1990s, contrary to the decrease of profits such as operating income to sales (OIS)[1] in Japan's electrical machinery firms, only Canon demonstrated its increasing trend. This contrasting performance corresponds to its consistent efforts to develop technological diversification over the last four decades.

While almost all electrical machinery firms decreased such diversification efforts in the 1990s, Canon's contrasting structure provides a constructive suggestion for survival strategy to electrical machinery firms suffering from income stagnation amidst megacompetition in an information society.

Prompted by this observation, this paper analyzes Canon's scenario for sustainable growth and its technological diversification dynamism with special attention to its contribution to high level of profits. On the basis of the identification of the correlation between technological diversification and assimilation of spillover technology, comparative empirical analyses are conducted focusing on the consequence of technological diversification and development trajectory in Japan's leading electrical machinery firms over the last two decades.

The significance of technological diversification has shifted to the relevance with assimilation of spillover technology while central issue of business diversification has moved to a prosperous business field. This shift was triggered by the technology distance concept postulated by Griliches [1]. Following this concept, Jaffe [2] developed new concepts of technological proximity and technological position. An empirical analysis was conducted by Goto and Suzuki [3,4] utilizing R&D diversification function as a proxy of assimilation of spillover technology in Japan's electrical machinery industry.

Focus of research then shifted to firm's capability to utilize spillover technology for technological diversification. The concept of adaptive capacity was introduced by Cohen and Levinthal [5,6] to explain the capability adapting spillover technology to indigenous technology. Prompted by Cohen and Levinthal [5,6], Watanabe et al. [7] developed the concept of assimilation capacity consisting of the ability for the perception, selection and incorporation of spillover technology.

While the importance of technological diversification has increased amidst megacompetition spurred by informatization and economic globalization in the 1990s, Japanese firms concentrated on their core business due to the economic stagnation after the bursting of the bubble economy [8]. Servas [9], Rajan et al. [10], and Scharfstein and Stein [11] postulated that research focus of the business diversification should shift to the evaluation of cost expansion accompanied with diversification from the viewpoint of excessive value approach. Therefore, the significant role of technological diversification is how to overcome this problem by constructing a virtuous cycle for an effective utilization of potential resources in innovation.

[1] The operating income is a measure of a company's earning power from ongoing operations, equal to earnings before deduction of interest payments and income taxes. It is also called operating profit or EBIT (earnings before interest and taxes). The OIS is the operating income per sales.

To date, while a number of studies have analyzed the significance of firm's technological diversification strategy, none has analyzed the dynamism of diversification in the context of the subsequent income structure.

Thus, the focuses of this paper are twofold: first, the measurement of technological diversification trajectory in leading electrical machinery firms based on the relationship between technology spillover and R&D diversification, second, the correlation analysis between the technological diversification and the profits such as OIS that could be a foundation in elucidating the dynamism of technological diversification leading to high income structure.

Section 2 reviews theoretical background of R&D diversification and assimilation of spillover technology. Section 3 measures the extent of technological diversification. Section 4 analyzes the contribution of technological diversification to high income structure. Section 5 briefly summarizes new findings, their policy implications and future works.

2. R&D diversification and assimilation of spillover technology

2.1. Increasing dependency on spillover technology

Amidst megacompetition, stimulated by the advancement of IT and consequent globalizing economy, the dependency on spillover technology has become significant [12,13]. In Japan, economic stagnation after the bursting of the bubble economy and consequent R&D stagnation have accelerated this trend [14].

Table 1 summarizes the trend in assimilated spillover technology from other firms in 24 Japan's leading electrical machinery firms over the period 1980–1998. As clearly observed in Fig. 1, not a few firms demonstrate their increasing dependency on spillover technology in the 1990s. These trends demonstrate the significance of effective utilization of spillover technology in a global context.

2.2. Technology distance, technological proximity and technological position

2.2.1. Technology distance

Griliches [1] postulated that knowledge stock levels of firms depend on not only their indigenous R&D investment but also knowledge stock developed by other firms. He postulated that the latter effects the spillover of technology as depicted by the following equation:

$$Y_i = BX_i^{1-\gamma}K_i^{\gamma}K_{ai}^{\mu} \tag{1}$$

where Y_i: production of i industry; B: scale factor; X_i: labor and capital; K_i: indigenous knowledge stock; K_{ai}: spillover knowledge stock; and γ, μ: coefficients.

$$K_{ai} = \sum\sum_j w_{ij}K_j$$

where w_{ij}: weight function enabling the spillover from j to i industry.

Table 1
Trends in dependency on assimilated spillover technology—24 of Japan's leading electrical machinery firms (1980–1998)

	Canon	Matsushita	NEC	Hitachi	Toshiba	Fujitsu	Melco	Sony	Sharp	Sanyo	MEW	JVC	Fuji	Kyocera	Oki	Pioneer	Alps	Casio	Rohm	Aiwa	Yokogawa	JRC	Meidensha	Kokusai
1980	.29	.29	.34	.35	.36	.33	.35	.35	.33	.27	.35	.32	.36	.44	.33	.35	.34	.34	.37	.31	.31	.35	.31	.20
1981	.30	.30	.34	.35	.35	.33	.34	.35	.33	.27	.34	.32	.36	.42	.33	.34	.34	.33	.37	.31	.31	.34	.31	.22
1982	.31	.30	.34	.35	.35	.33	.34	.34	.33	.27	.33	.33	.35	.40	.33	.34	.34	.33	.36	.31	.32	.34	.31	.24
1983	.32	.31	.34	.34	.34	.33	.34	.34	.33	.28	.33	.33	.34	.39	.33	.33	.34	.33	.36	.31	.32	.34	.31	.26
1984	.32	.31	.34	.34	.34	.33	.34	.34	.33	.29	.33	.34	.34	.38	.33	.33	.34	.33	.36	.31	.32	.34	.31	.28
1985	.32	.32	.34	.34	.34	.33	.34	.34	.33	.30	.33	.34	.34	.37	.33	.33	.34	.33	.35	.32	.32	.34	.31	.29
1986	.33	.32	.34	.34	.34	.34	.33	.34	.33	.30	.32	.33	.34	.37	.33	.33	.34	.33	.35	.32	.33	.34	.31	.30
1987	.32	.31	.34	.34	.34	.33	.34	.34	.33	.28	.33	.33	.34	.38	.33	.33	.34	.33	.36	.31	.32	.34	.31	.26
1988	.33	.32	.34	.34	.34	.34	.33	.33	.34	.28	.32	.33	.33	.36	.33	.32	.33	.35	.35	.31	.33	.34	.32	.32
1989	.34	.34	.34	.33	.33	.34	.33	.34	.33	.34	.32	.34	.32	.29	.33	.32	.33	.31	.32	.33	.34	.33	.33	.35
1990	.34	.34	.33	.32	.33	.35	.33	.35	.31	.39	.32	.32	.32	.31	.32	.33	.25	.34	.30	.35	.35	.32	.34	.38
1991	.35	.34	.30	.32	.32	.37	.33	.35	.31	.38	.32	.32	.32	.35	.34	.32	.26	.30	.34	.39	.35	.31	.30	.36
1992	.35	.33	.29	.32	.32	.37	.34	.35	.32	.36	.32	.32	.31	.37	.36	.33	.25	.27	.36	.41	.34	.30	.32	.36
1993	.35	.33	.28	.33	.32	.36	.34	.37	.33	.36	.33	.31	.31	.38	.36	.34	.12	.30	.38	.39	.33	.31	.33	.36
1994	.35	.33	.28	.33	.32	.36	.32	.38	.34	.36	.34	.30	.26	.39	.33	.35	.19	.32	.36	.38	.33	.32	.33	.37
1995	.37	.33	.26	.32	.33	.36	.30	.38	.35	.38	.35	.28	.31	.35	.32	.37	.26	.34	.36	.41	.32	.33	.33	.37
1996	.39	.32	.25	.32	.34	.33	.30	.38	.37	.39	.37	.27	.32	.28	.25	.39	.23	.36	.38	.43	.31	.34	.34	.37
1997	.41	.31	.27	.31	.34	.31	.30	.38	.38	.39	.37	.27	.30	.25	.22	.38	.14	.36	.40	.44	.28	.36	.34	.33
1998	.40	.31	.30	.29	.34	.32	.30	.39	.37	.37	.36	.29	.29	.32	.26	.36	−.37	.33	.41	.44	.29	.35	.31	.35

$$\text{DAST} = \frac{ZT_s}{T_i + ZT_s}$$

where T_i: indigenous technology stock; T_s: spillover technology pool, $T_s = \sum_{j=1}^{24} T_j \ (j \neq i)$; and assimilation capacity $Z = \frac{1}{1 + \frac{\Delta T_s / T_s}{\Delta T_i / T_i}} \frac{T_i}{T_s}$ (Watanabe et al. [7]).

Melco: Mitsubishi Electric; MEW: Matsushita Electric Works; JVC: Victor Company of Japan; and JRC: Japan Radio Company.

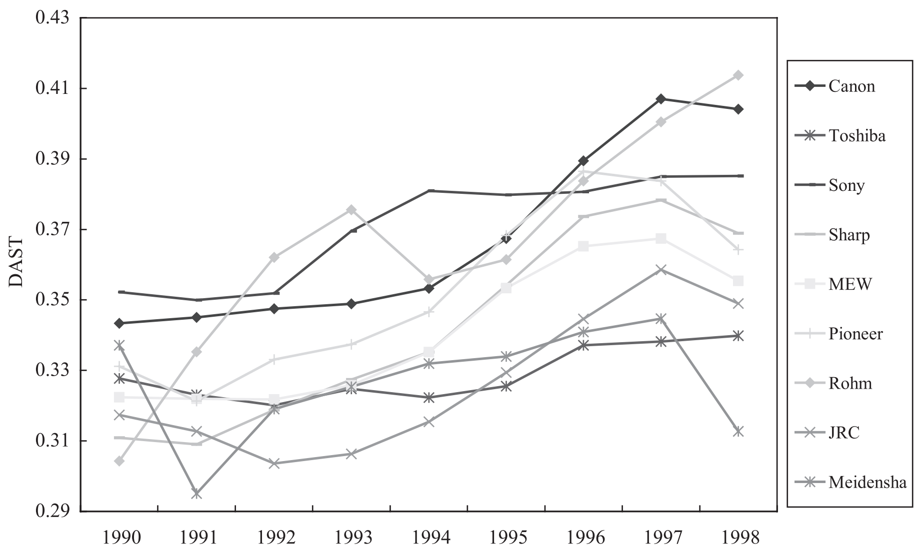

Fig. 1. Trend in dependency on assimilated spillover technology of Japan's leading electrical machinery firms (1990–1998).

Griliches [1] demonstrated that effective utilization of spillover technology is subject to this weight function that is solely dependent on the technology distance between donor and host firms. This has two important implications.

(a) First, those firms very close to host firm share similar products as well as R&D, thereby developed such infrastructure as manufacturing facilities, R&D resources and marketing networks leading to easy utilization and absorption of spillover technology.
(b) Second, strong possibility to come across timely necessitated technology is expected.

Thus, he demonstrated the significance of effective utilization of spillover technology for the improvement of firm's collective knowledge level and its dependency on its efforts to shortening technology distance.

2.2.2. Technological proximity and technological position

Jaffe [2], stimulated by Griliches's [1] suggestion, postulated a new concept of technological position based on the R&D similarity of host and donor firms measured by technological proximity as practical technological distance between the two firms.

Given the technological position of firm i, the technological distance between firms i and j, P_{ij} can be depicted by the following equation:

$$P_{ij} = \frac{F_i F_j'}{[(F_i F_i')(F_j F_j')]^{1/2}} \tag{2}$$

where F_i: distribution of R&D expenditure in firm i, $F_i=(F_{i1}\cdots F_{ij}\cdots F_{in})$; F_i': transpose vector; and F_{ij}: ratio of R&D expenditure in the field of j expensed by firm i.

This distance varies between 0 and 1 and it approaches 1 as the proximity increases.

Utilizing this equation, assimilated spillover technology of firm i out of total R&D investment in donor firm j, $[R_i]_j$ can be measured by the following equation:

$$[R_i]_j = R_j P_{ij} \tag{3}$$

2.3. R&D diversification and technological distance

On the basis of the concept of technology distance, assimilation capacity which plays a key role in effective utilization of spillover technology, is governed by the proximity of technological position of both donor and host sides.

Technological distance could be maximized when the proximity of technological position corresponds each other. This proximity depends on the similarity of R&D activities between the donor and the host.

This is because when the host conducts similar R&D activities of the donor it can realize the trend, existence and absorbability of spillover technology for the effective and advantageous introduction, absorption and development of spillover technology.

Diversification of R&D is a strategy in line with this direction and actively employed during the course of the 1980s in Japan [15].

Given R_{ij} is the R&D expenditure in the field of j out of R&D expenditure of sector i, R_i, the ratio of R&D investment initiated by sector i, D_i can be depicted by the following equation:

$$D_i = R_{ii}/R_i \tag{4}$$

Thus, diversification ratio D_{ni} can be expressed as follows:

$$D_{ni} = 1 - D_i = 1 - R_{ii}/R_i \tag{5}$$

This ratio can be also measured as a function of Herfindahl Index (HHI) as follows:

$$D_{ni} = f(\text{HHI}),\ \text{HHI} = 1 - \Sigma P_i^2 \tag{5'}$$

where $P_i = R_{ii}/\Sigma R_{ii}$.

Utilizing the diversification ratio, the technological distance in Eq. (1) can be depicted as follows:

$$P_{ij} = \frac{\sum_k \frac{R_{ik}}{R_i}\frac{R_{jk}}{R_j}}{\left[\sum_j \frac{R_{ij}^2}{R_i}\sum_i \frac{R_{ji}^2}{R_j}\right]^{1/2}} \tag{6}$$

Thus, technology assimilated by sector i out of R_j initiated by sector j can be depicted as the follows by means of the product of R_j and P_{ij} [3,4]:

$$[R_i]_j = R_j P_{ij} = F(D_{ni}) \tag{7}$$

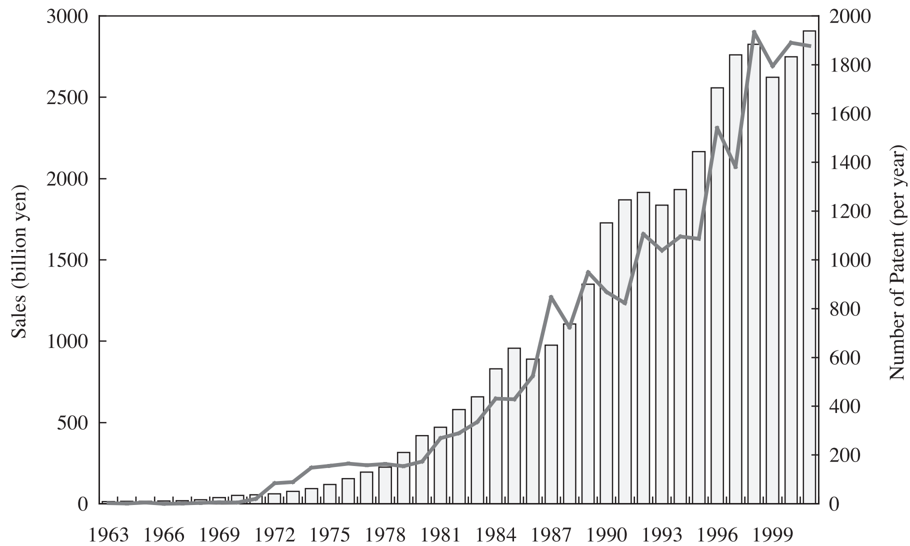

Fig. 2. Trends in number of patents registered in the United States and sales of Canon (1963–2001). Source: Canon (2001) [17].

Since D_{ni} is a function of HHI as depicted in Eq. (5′), assimilated spillover technology ($[R_i]_j$) in Eq. (7) can be depicted as a function of HHI as follows:

$$[R_i]_j = H(\mathrm{HHI}) \tag{7'}$$

Eq. (7′) enumerates a correlation between technological diversification represented by HHI and assimilated spillover technology.

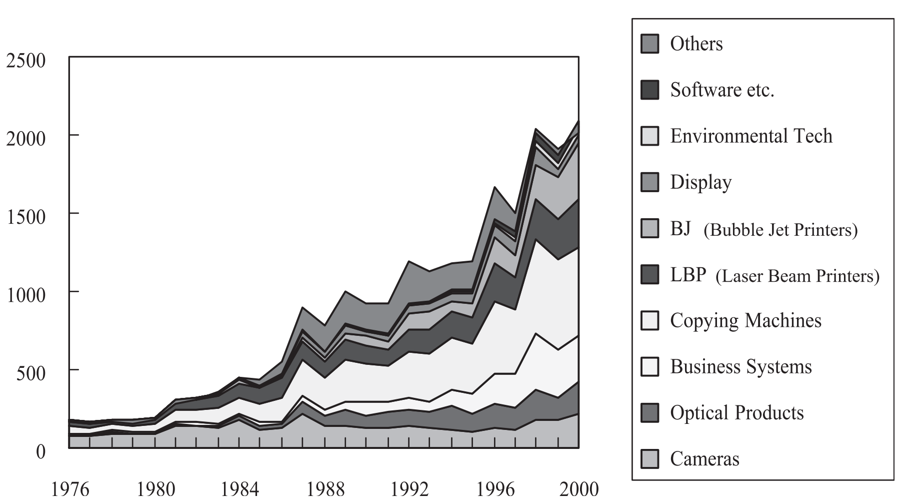

Fig. 3. Canon's technology development trajectory by means of patents registered in the United States (1976–2000).

3. Measurement of technological diversification

3.1. Measurement of Canon's technology development trajectory

Canon's technology development trajectory can be represented by the trend in patents registered in the United States [16]. This trend demonstrates very strong correlation with that of its sales as illustrated in Fig. 2.

Based on these observations, Canon's technology development trajectory can be measured utilizing patents extraction method classifying 20,252 Canon's patents registered in the United States over the period 1976–2000 into 33 technological fields.

Fig. 3 illustrates these trends by integrating into 10 technological fields. Tabulated number of patents demonstrated in Fig. 3 as a proxy of Canon's technology development trajectory by technological fields is summarized in Table 2.

These 10 technological fields are (i) cameras, (ii) optical products, (iii) business systems (information and communication equipment), (iv) copying machines, (v) laser beam printers

Table 2
Canon's patents numbers registered in the United States (1976–2000)

	Cameras	Optical products	Business systems	Copying machines	LBP	BJ	Display	Environmental tech	Software	Others
1976	74	7	10	47	35	1	0	1	0	0
1977	75	5	16	35	21	6	3	0	0	3
1978	95	4	11	40	23	1	0	0	0	0
1979	88	5	15	34	27	2	4	1	0	0
1980	85	5	12	49	33	3	1	0	0	0
1981	135	21	12	81	55	3	4	1	0	0
1982	136	11	14	80	66	5	0	3	0	0
1983	126	15	14	96	85	6	1	1	4	6
1984	178	23	14	106	86	23	13	3	0	0
1985	116	26	19	125	93	7	10	4	3	39
1986	127	23	12	155	134	11	9	3	3	80
1987	216	74	38	235	118	27	32	5	8	141
1988	143	68	35	199	100	32	33	5	4	169
1989	146	94	54	270	132	38	45	9	13	201
1990	127	79	83	253	107	64	30	8	7	169
1991	134	100	66	232	98	49	36	8	6	190
1992	143	101	76	292	146	103	46	7	8	276
1993	127	102	66	310	155	108	58	7	6	186
1994	115	154	105	325	175	62	53	13	13	169
1995	103	116	126	318	174	84	68	12	18	171
1996	128	159	192	455	247	160	79	17	26	203
1997	121	138	219	413	205	138	87	31	36	111
1998	184	182	365	600	259	216	115	39	56	28
1999	176	141	311	576	253	269	62	35	45	37
2000	224	199	300	565	302	357	59	49	39	0

Table 3
Patents extraction formula for the analysis of Canon's technological development

Field	Patents extraction formula
Whole fields	AN/Canon and ISD/$/$/1998
Cameras	AN/Canon and ((ICL/G02B0$ or ICL/G03B0$ or ICL/G03C0$ or ICL/G03D0$) and not (ICL/G03B027/$ or ICL/G03B042/$)) and ISD/$/$/1998
Optical products	AN/Canon and (ICL/G03B042/$ or ICL/G03C005/16 or ICL/H05G0$ or ICL/H01J035/$ or ICL/A61B0$ or ICL/G03F0$ or ICL/H01L0$ or ABST/ray or ABST/semiconduct$) and ISD/$/$/2000
Business systems	AN/Canon and (ICL/G06F0$ or ICL/G11C0$ or ICL/G06K0$ or ABST/calculat$ or ABST/computer$) and ISD/$/$/2000
Copying machines	AN/Canon and (ABST/copy$ or ABST/photocopy$ or ABST/toner$ or ABST/photoconductor$ or ABST/develop$ ICL/G03B027/$ or ICL/H04N$ or ABST/fax$ or ABST/scan$) and ISD/$/$/1978
LBP	AN/Canon and ICL/G03G0$ and ISD/$/$/2000
BJ	AN/Canon and ICL/B41J0$ and ISD/$/$/2000
Display	AN/Canon and (ICL/G02F001/13$ or ICL/C09K019/$ or (ABST/liquid$ and ABST/crystal$) or ABST/LCD) and ISD/$/$/2000
Environmental technology	AN/Canon and (ICL/C12$ or ABST/ecology$ or ABST/recycl$ or ABST/biolog$ or ABST/biochem$ or ABST/environment$ or ABST/wast$ or ABST/remed$) and ISD/$/$/2000
Software	AN/Canon and (ABST/softwar$ or ABST/program$ or ABST/manag$) and ISD/$/$/2000

(LBP), (vi) bubble jet printers (BJ), (vii) liquid crystal display, (viii) environment technology, (ix) software technology, (x) miscellaneous and those patents extraction method is summarized in Table 3.

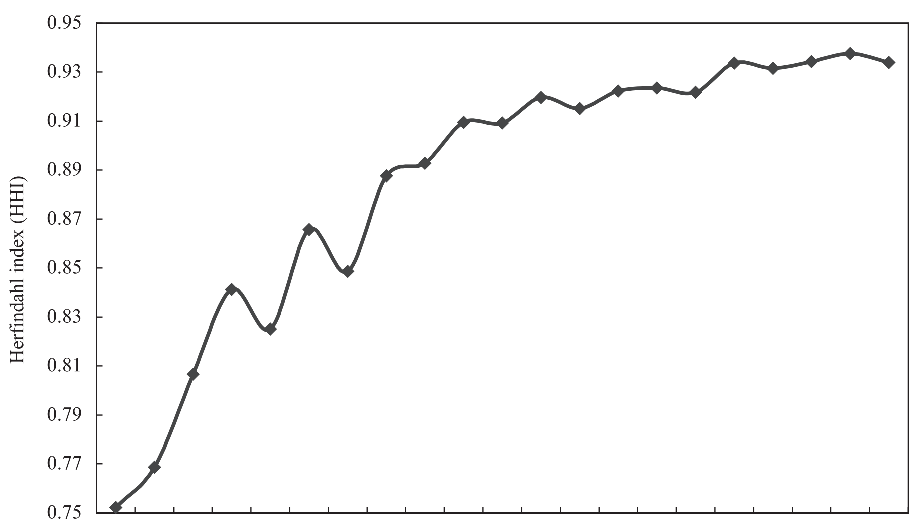

Fig. 4. Trends in Canon's technological diversification (1978–1998).

Table 4
Chronology of Canon's technological diversification strategy

Period	Management decision	Organization	Products	Technology
~1960	⟨Embryo period of diversification⟩ 45 Declaration for revival 47 Canon Camera Co. Ltd. ⟨Diversification planning period⟩	55 New York branch 57 Distribution post in Europe	40 X-ray camera 59 Synchroreader	Optics, precision machinery + Electronics
~1970	62 First five year plan ⟨Declaration of diversification⟩ 67 Slogan "cameras in right hand, business products in left hand" 69 Canon Inc.	62 Canon Latin America 62 Product research dept. 64 Project base system 69 Central R&D institute 70 Production base in Taiwan	61 Canonnet 61 Microfilm system 64 Calculator 68 Original electro-photography 70 Copying machine	+ Electrophotography recording
~1980	⟨Diversification development period⟩ 76 Premier company plan	72 Production base in Germany 74 Production base in California 77 Business division system	75 LBP 76 AE-1, facsimiles 79 LBP-10 80 Japanese word processor	+ Laser recording
~1990	85 Tie-up with HP in computer business 88 Restart with global company plan	81 Corporate development center 83 Production base in France 84 Production of copying machines in China 88 R&D center in UK 90 Overseas labs (America, Australia, France)	81 BJ 82 PC-10/20 84 LBP-CX 85 Optical card R/W 90 BJ-10	87 Optics, precision macinery, production, electronics, recording, memory, new recording, software, communication, system, biotechnology
~2000	98 Management renovation commitee	92 Canon Chemicals 93 Ecology R&D center 96 Fuji-Susono research park 98 Joint venture with Beijing University 99 Ayase office (semiconductor)	91 FLCD 92 BJC-full color bubble jet printer 95 Optical card system 96 Advanced photo system camera 99 Surface-conduction electrion emitter display 00 Compact digital video camcorder	21 key technologies Precison recording, optics, instrument & control, production process, image processing, memory, opto-electronics, semiconductor, display,etc.

Source: Canon [17].

3.2. Measurement of technological diversification

Utilizing Canon's technological development trajectory classified into 33 technological fields, and depending on Eq. (5′), trends in Canon's technological diversification represented by Herfindahl index over the period 1978–1998 are measured. Fig. 4 illustrates these trends that demonstrate chronology of Canon's technological diversification strategy as summarized in Table 4 [17].

Utilizing both trends in Canon's HHI (Fig. 4) and assimilated spillover technology (Table 1) and based on Eq. (7′), correlation analysis between technological diversification and dependency on assimilated spillover technology over the period 1980–1998 is conducted.

$$\ln\mathrm{DAST} = \underset{(-90.04)}{-0.990} + \underset{(13.78)}{0.976}\ln\mathrm{HHI} - \underset{(-3.28)}{0.065}D_{87}$$
$$\text{Adjusted } R^2 = 0.922 \; DW = 1.61 \quad (8)$$

where DAST: dependency on assimilated spillover technology; HHI: Herfindahl index; and D_{87}: dummy variable (starting year of the bubble economy).

Eq. (8) indicates extremely high statistical significance and demonstrates significant correlation between DAST and HHI in Canon over the period 1980–1998.

A postulate on the relationship between R&D diversification and technology distance as reviewed in section 2.3 suggests that Eq. (8) represents the correlation between

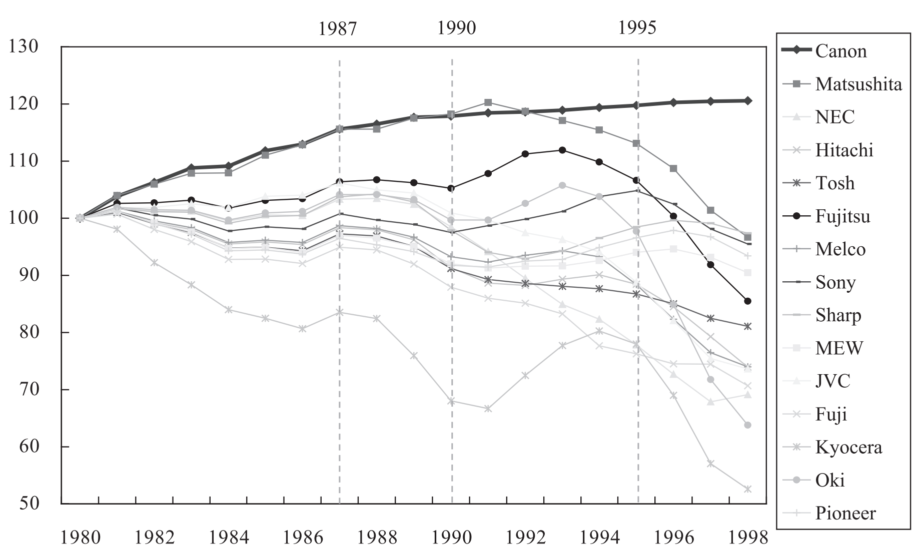

Fig. 5. Trends in technological diversification of 15 leading electrical machinery firms (1980–1998)—HHI: 1980 = 100, 3 years moving average.

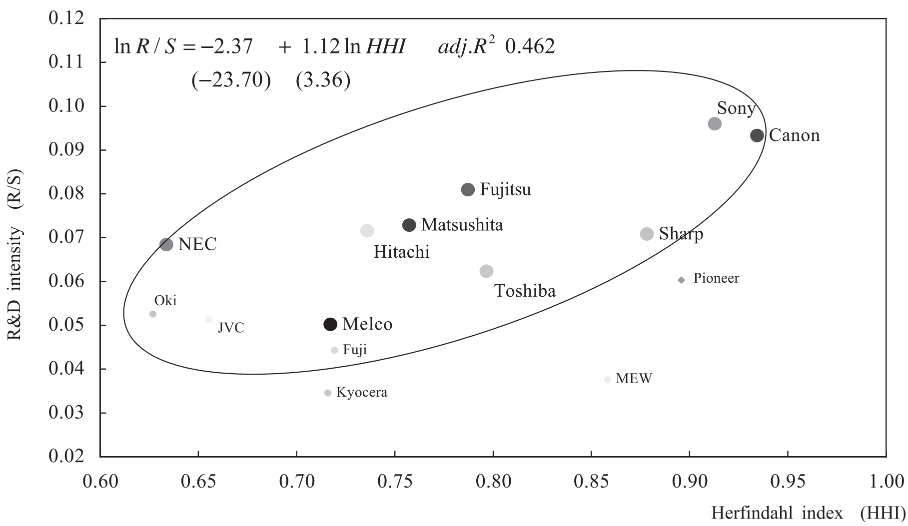

Fig. 6. Correlation between technological diversification and R&D intensity in 15 leading electrical machinery firms (1995–1998). R/S: R&D intensity (R&D expenditure per sales in 1990 fixed price).

technological diversification and assimilated spillover technology not only in Canon but also common to firms consisting technology spillover pool (in case of the analysis in Table 1, 24 electrical machinery firms). Therefore, based on this correlation and utilizing assimilated spillover technology measured in Table 1, the trend in technological diversi-

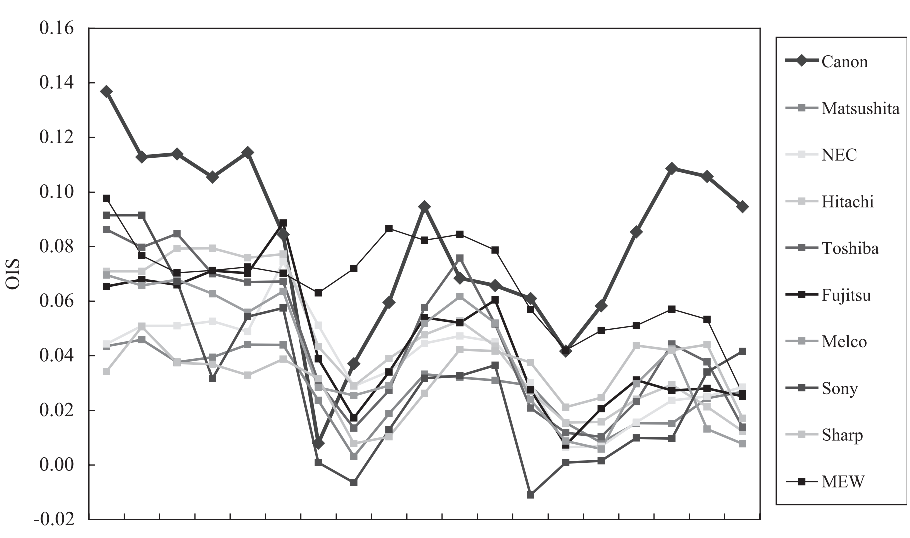

Fig. 7. Trends in OIS of 10 leading electrical machinery firms (1980–1998).

Table 5
Comparison of OIS of 10 leading electrical machinery firms (1980–1998)

	1980–1986	1987–1990	1991–1994	1995–1998
Canon	0.10	0.06	0.06	0.10
Matsushita	0.04	0.02	0.02	0.02
NEC	0.05	0.04	0.02	0.02
Hitachi	0.07	0.04	0.03	0.02
Toshiba	0.07	0.04	0.02	0.03
Fujitsu	0.07	0.04	0.03	0.03
Melco	0.06	0.04	0.02	0.02
Sony	0.06	0.02	0.01	0.02
Sharp	0.04	0.02	0.03	0.04
MEW	0.07	0.08	0.06	0.05

1980–1986: after the second energy crisis and before the bubble economy; 1987–1990: during the bubble economy; 1991–1994: after the bubble economy and before the economic stagnation; and 1995–1998: during the severe economic stagnation.

fication in each respective firm in electrical machinery industry as listed in Table 1 can be measured.

Results of the analysis on trends in technological diversification of 15 leading electrical machinery firms out of 24 firms measured by this approach are demonstrated in Fig. 5.

Looking at Fig. 5, we note that while technological diversification has activated in the 1980s, almost all firms decreased their diversification in the 1990s as a consequence of the shift of business strategy to selection and concentration. These trends correspond to the proceeding empirical analysis [8].

Noteworthy is that in this trend only Canon has maintained further diversification. Fig. 6 analyzes the correlation between technological diversification and R&D intensity and demonstrates clear positive correlation between them. Canon that leads the highest technological diversification ratio together with Sony demonstrates the highest R&D intensity.

4. Contribution of technological diversification to OIS

4.1. Trends in OIS in 10 leading electrical machinery firms

Fig. 7 as well as Table 5 demonstrates the trend in OIS, a measure of a company's per sales earning power from ongoing operation, equal to earnings before deduction of interest payments and income taxes, of 10 leading electrical machinery firms (top 10 firms with respect to sales volume excluding Sanyo[2]) over the period 1982–1998.

[2] Sanyo (10th sales volume in 1998) was excluded as it was not necessarily R&D intensive firm in the early 1980s.

Table 6
Trends in Canon's sales composition (1980–1998): %

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Cost of goods manufactured	51.0	54.0	52.7	52.6	54.4	54.8	59.8	60.6	58.0	57.0	55.8	56.2	58.6	61.4	61.2	61.3	59.3	57.3	57.4
Selling cost	9.0	9.2	9.1	9.2	9.0	9.1	9.3	8.7	8.5	8.6	8.7	9.1	8.4	8.3	8.2	7.8	7.9	8.1	8.2
General administrative expenditure	25.7	26.6	26.7	27.0	26.5	26.8	27.5	25.9	25.6	25.8	26.2	27.3	25.3	25.1	24.9	23.7	24.2	24.7	25.1
Operating income	14.3	10.3	11.5	11.2	10.1	9.3	3.4	4.7	7.9	8.6	9.2	7.4	7.7	5.3	5.7	7.2	8.6	10.0	9.3
Sales	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Looking at these figure and table, we note that while Canon declined its OIS in the middle of the 1980s and in the beginning of the 1990s, it recovered immediately and maintained high level of OIS.

It is noteworthy that while other electrical machinery firms decreased their OIS in the 1990s, only Canon increased its OIS and has maintained high level of OIS.

Table 6 summarizes trends in Canon's sales composition on which its OIS depends. As illustrated in Fig. 8, its selling cost has demonstrated dramatic decrease, particularly in the 1990s, which is considered the main source of maintaining high level of OIS compared with those of other firms [17].

4.2. Analysis of contributing factors to OIS

Contributing factors to OIS of electrical machinery firms are analyzed. It is generally postulated that OIS in high-technology firms are governed by economic situation, exchange rate as well as firms' technopreneurship strategy [14]. Therefore, the following function depicting governing factors of OIS is formulated by incorporating diversification strategy as technopreneurship strategy.

$$\mathrm{OIS} = A(\mathrm{CI})^{b}(\mathrm{YR})^{c}(\mathrm{HHI})^{d}e^{\lambda t} \tag{9}$$

where A: scale factor; CI: economic situation (composite index); YR: exchange rate (Yen per dollar); t: time trend; b, c, d, λ: elasticity of each factor.

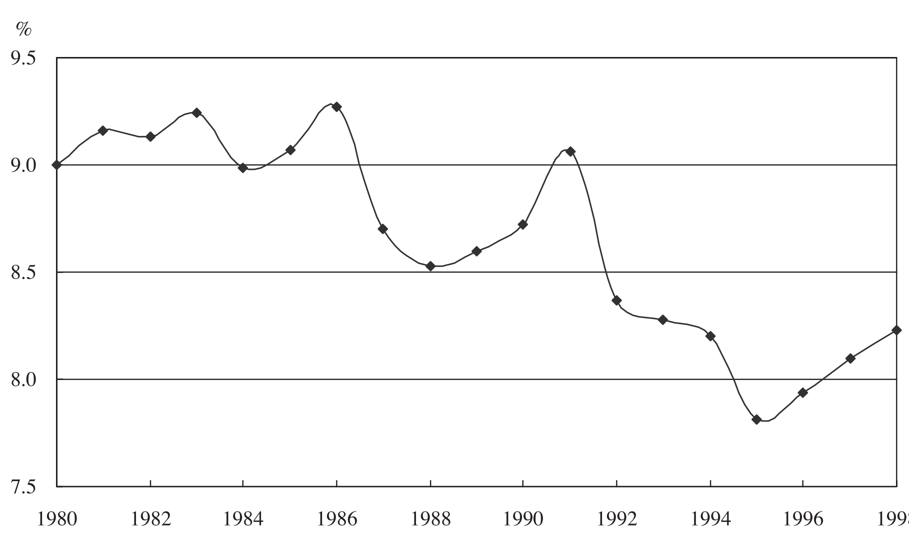

Fig. 8. Trends in the ratio of selling cost out of Canon's total sales (1980–1998).

Utilizing Eq. (9), governing factors of OIS of 10 leading electrical machinery firms are analyzed by Eq. (10).

$$\ln \text{OIS} = a + b\ln \text{CI} + c\ln \text{YR} + d_1 D_{1980-1986}\ln(\text{HHI}_i) + d_2 D_{1987-1990}\ln(\text{HHI}_i) + d_3 D_{1991-1994}\ln(\text{HHI}_i) + d_4 D_{1995-1998}\ln(\text{HHI}_i) + \lambda t \quad (10)$$

where D is a coefficient dummy variable corresponding to the classification depending on Japan's economic situation as indicated in Table 5.

$$\begin{pmatrix} D_{1980-1986}: 1980-1986=1 \quad \text{others}=0, & D_{1987-1990}: 1987-1990=1, \quad \text{others}=0 \\ D_{1991-1994}: 1991-1994=1 \quad \text{others}=0, & D_{1995-1998}: 1995-1998=1, \quad \text{others}=0 \end{pmatrix}$$

Results of the analysis are summarized in Table 7 which demonstrated conspicuously high Canon's technological diversification elasticity to OIS, suggesting that Canon's technological diversification contributed significantly to OIS and effects of economic situation (CI) as well as exchange rate (YR) were not so significant.

Table 7

Factors contributing to OIS in 10 leading electrical machinery firms (1980–1998)

$$\ln \text{OIS} = a + b\ln \text{CI} + c\ln \text{YR} + d_1 D_{1980-1986}\ln(\text{HHI}_i) + d_2 D_{1987-1990}\ln(\text{HHI}_i) + d_3 D_{1991-1994}\ln(\text{HHI}_i) + d_4 D_{1995-1998}\ln(\text{HHI}_i) + \lambda t$$

	a	b	c	d_1	d_2	d_3	d_4	λ	Adjusted R^2	DW
Canon	−1.47	0.48	−0.54	1.89	52.35	55.76	49.63	−0.13	0.955	2.78
	(−0.35)	(0.73)	(−1.22)	(0.53)	(3.44)	(3.48)	(3.17)	(−1.83)		
Matsushita	−24.37	3.28	−1.52	7.27	8.87	−1.80	−3.70	−0.16	0.889	2.00
	(3.03)	(1.80)	(2.88)	(1.36)	(1.65)	(0.57)	(−1.60)	(−1.44)		
NEC	−21.94	2.11	−1.66	1.04	8.42	5.06	2.90	0.10	0.850	1.69
	(−3.94)	(1.78)	(−2.81)	(0.18)	(1.67)	(1.99)	(1.69)	(1.91)		
Hitachi	−17.59	1.96	−1.12	1.53	4.47	3.62	2.73	–	0.900	1.61
	(−5.17)	(2.84)	(−4.13)	(0.54)	(1.70)	(2.59)	(3.32)			
Toshiba	−18.86	2.25	−1.81	−4.33	−12.29	15.59	7.00	−0.13	0.891	2.45
	(3.75)	(2.40)	(−2.50)	(−0.72)	(−1.68)	(1.72)	(0.86)	(1.36)		
Fujitsu	−20.14	2.53	−1.12	0.136	6.02	3.40	1.25	–	0.933	2.56
	(−5.98)	(3.39)	(−2.96)	(0.04)	(1.61)	(0.74)	(1.37)			
Melco	−29.01	4.41	−1.17	6.60	13.38	8.72	3.72	–	0.630	1.59
	(3.25)	(2.35)	(−1.62)	(0.95)	(1.73)	(1.76)	(1.82)			
Sony	−72.37	7.61	−6.91	48.82	30.07	22.08	−4.75	–	0.788	2.32
	(−5.03)	(2.50)	(−6.35)	(3.64)	(2.10)	(1.83)	(−0.57)			
Sharp	−11.51	0.39	−0.85	−17.37	−16.15	−12.85	−21.47	–	0.567	2.19
	(−1.92)	(0.29)	(−1.17)	(−2.53)	(−2.57)	(−3.77)	(−4.38)			
MEW	−10.70	2.41	0.48	4.14	10.17	−3.04	2.41	–	0.884	2.62
	(−5.14)	(5.88)	(2.03)	(2.86)	(5.41)	(−2.79)	(4.04)			

Table 8
Comparison of decreasing effects of COGM, selling cost and general administrative expenditure by means of technological diversification in Canon (1980–1998)

$\ln X = a + b \ln \mathrm{HHI}$

X	a	b	Adjusted R^2	DW
C/S	– 0.46 (– 22.67)	0.99 (5.76)	0.642	1.22
Sell/S	– 2.54 (– 109.81)	– 0.85 (– 4.33)	0.496	1.02
GA/S	– 1.41 (– 65.03)	– 0.47 (– 2.54)	0.232	0.94

S: sales; C: COGM; Sell: selling cost; GA: general administrative expenditure; and HHI: Herfindahl index.

OIS is governed by the share of cost of goods manufactured (COGM), selling cost as well as general administrative expenditure. Since sales of R&D intensive electrical machinery firms depend largely on innovative products, the selling cost greatly influences their OS.

However, given the new innovative products are attractive enough, a firm can increase its sales without depending on increase in selling cost.

As analyzed in Fig. 8, Canon decreased dramatically its dependency on selling cost in 1990s and this seems to be the major source on maintaining high level of OIS.

Suggested by these observations, the effects of technological diversification to decrease in COGM, selling cost and general administrative expenditure are analyzed and the results are summarized in Table 8, which suggests that both selling cost and general administrative expenditure, particularly selling cost, can be decreased as technological diversification is developed.

Based on these findings, the following scheme can be envisaged: increase in technological diversification → increase in functionality development[3] [14] → decrease in dependency on selling cost → increase in OIS.

Furthermore, the increased OIS can be envisaged to induce further technological diversification leading to a virtuous cycle between the technological diversification and the increase in OIS. This virtuous cycle is triggered by the increase in functionality development by means of the effective assimilation of spillover technology and this is considered the source of Canon's sustainable growth while other rival firms have been suffering from the decrease of their OIS in the 1990s.

5. Conclusion

Prompted by conspicuous Canon's behavior with respect to its technological diversification as well as high level of OIS, this paper attempted to elucidate the relationship between them. Based on a theoretical relationship between assimilation capacity of spillover technology and diversification of R&D activities, new methodology to measure the extent of technological diversification of firms by means of assimilated spillover technology was developed.

[3] The functionality development is generally defined as the ability to dramatically improve the performance of production processes, goods and services by means of innovation.

Utilizing this methodology, technological diversification trend in Japan's leading electrical machinery firms was measured and its impacts on R&D intensity were analyzed. The regression analyses revealed that Canon's technological diversification has strongly supported its high level of OIS compared with those of other Japan's leading electrical machinery firms.

Furthermore, the analysis of the sensitivity of sales components to the technological diversification suggested that a virtuous cycle between the technological diversification and the increase in OIS can be the source of Canon's sustainable growth and this cycle is triggered by the increase in functionality development by means of the effective assimilation of spillover technology.

Canon's diversification strategy provides a constructive suggestion for effective utilization of spillover technology, which is considered the key of competitiveness in an increasing trend in global technology spillover.

However, it is generally pointed out that while firms with sufficient business resources in core business field possess high ability to diversify, such sufficient resources fringe from diversification. Canon's virtuous cycle is against this general postulate. Therefore, future works should focus on the elucidation of the dynamism inducing Canon's technological diversification.

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