
論文

Globalization and Networking of R&D Activities

— Analysis Centering Around the Cases of IBM Corp.,
Philips N.V. and NEC Corp. —

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Abstract

This paper examines to what extent and how IBM Corp., Philips N.V. and NEC Corp., U.S., European and Japanese electric, electronic and computer multinationals, develop their R&D activities on a global scale. In this paper, I will clarify their extent of internationalization and networking of R&D by these Multinationals in the field of industrial technology and basic research by taking an approach which refers to US patents and scientific papers published as results of R&D activities. The main finding of this research is that globalization and networking of R&D activities of these companies demonstrate high standards and are continuing to progress both in terms of basic research and industrial engineering. And most importantly, it may be suggested that there is a drastic evolution towards international networking R&D structures in the fields of basic research of multinationals.

Key Words : Research and Development(R&D), Globalization, Networking, US Patents, Scientific Papers.

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1 Introduction

Current empirical studies about internationalization of Research and Development (R&D) have mainly been based on two approaches. One refers to the number of overseas R&D units, overseas R&D expenditures, the number of overseas R&D staff members, and their organizational missions etc., primarily based on questionnaire style data (Behrman, J. N. [1980], Dunning, J. (1992), Dunning, J. and Narula, R [1995], Florida, R. [1997], Hirota, T. [1986], Iwata, T. [1994], Kuemmerle, W. [1997], Papanastassiou, M. and Pearce, R. (1994), Ronstadt, R. [1977], Serapio, M. G. [1994], Serapio, M. and Dalton G. H. [1995], Takahashi, H. [1997]).

The other approach examines patents granted in the US, so that it can identify which overseas R&D operations or labs invented these patented technologies (Cantwell, J.[1991], Etemad, H. and Dulude, L. S.[1985], Hayashi, T.[1989], Patel, P.[1995], Patel, P and Pavitt, K. [1991], Pearce, R. D and Singh, S [1992].

However, there still seems to be mainly two unsolved issues as far as overseas R&D of Japanese companies are concerned. One issue is that while many researchers taking the former approach have revealed that Japanese companies have intensified their overseas R&D activities, particularly in the US, in terms of such input factors as R&D expenditures and the number of overseas R&D facilities, etc., some others taking the latter approach argue that these companies still concentrate their R&D activities at home so that their overseas R&D activities do not play key roles in their R&D performances but play roles similar to the 'Listening Posts'.

The other issue is that although some of these recent studies mentioned above have noticed, more or less, the tendency towards an international networking of R&D activities, the fact has not necessarily been revealed concretely.

In this paper, I shed light on these two issues by clarifying their extent of internationalization and networking of R&D²⁾ by three multinationals, IBM Corp., Philips N.V. and NEC Corp. I take an approach here referring to US patents and scientific papers as results of their R&D activities in the areas of industrial technology and basic research. One of the biggest merits of this approach is that nominal R&D operations are eliminated,

2) The term networking of R & D can be used in a broad sense including not only joint research among institutions, but also licensing agreements and other various kinds of strategic alliances. However, in this paper it is actually restricted to joint research.

so that the substantial R&D activities in these two R&D fields can be grasped. However, a critical point to be noted here is that results of R&D activities are not always mirrored on the number of patents granted. Namely, patented technologies could be mainly based on the inventions in the technological fields of industrial engineering centering on hardware technologies³⁾. These technologies are, therefore, rather produced in the latter processes of product development centering on hardware technology fields. On the other hand, the results of basic research that includes software technology fields could be rather assessed by searching through scientific papers published in technical journals. In fact, by taking this other approach, different overseas R&D patterns from the literatures have appeared which will be presented in the following section.

2 Globalization and networking of R&D at the level of industrial technology (industrial engineering)

Industrial engineering in R&D activities is rather addressed in the downstream in the processes of putting a concept into a product. I will examine here to what extent and in what structures the internationalization and networking of R&D activities of these companies have conducted in terms of industrial engineering. For this purpose, I employ here the method of searching through US patents so that we can identify who the inventors are and what their nationalities are. The main reason to search through US patents is to show that the more significant the invented technologies are, which are expected to exploit on a world wide level, the more likely they are tended to be applied for to the US which has the biggest market as a country and many competitors in the main technology fields. US patent data based on this section are obtained through [INPADOC], which is a database on patenting information.

- (a) Globalization and networking of R&D activities of IBM Corp. - in the fields of industrial technology

Table 1 illustrates a classification of the numbers of patents acquired by IBM Corp. in

3) In recent years, however, even such computerized "business methods" as a method of online advertising, purchasing and payment, online ordering using credit card, and a method of issuing and tracking electronic money, seem to be getting patented (Wall Street Journal, Oct.9, 1998).

Table 1 Globalization and Networking of R&D of IBM Corp.
(By the nationality of inventors of US Patents : Number of US patents)

	1980	1985	1990	1995
IBM USA Sole	344 (89.1%)	496 (85.4%)	519 (84.9%)	1178 (85.1%)
Number of Int'l Joint inventions	2 (0.9%)	12 (2.1%)	18 (2.9%)	42 (3.0%)
IBM Overseas Sole	40 (10.4%)	73 (12.6%)	74 (12.1%)	165 (11.9%)
(Japan)	0	3	15	56
(UK)	13	13	9	39
(France)	11	17	28	26
(Germany)	12	33	16	22
(Switzerland)	2	5	2	9
(Israel)	0	0	1	5
(Canada)	0	0	1	3
(Italy)	0	0	0	2
(Sweden)	0	1	1	1
(Ireland)	0	0	0	1
(India)	0	0	0	1
(Netherlands)	0	1	0	0
(Finland)	0	0	1	0
(Venezuela)	0	0	1	0
Total	386 (100.0%)	581 (100.0%)	611 (100.0%)	1385 (100.0%)
Number of nat'lites of IBM overseas(1)	4	7	10	11
Number of overseas nat'lities of joint inventors(2)	2	5	10	12
Total Number of Overseas Nat'lities	5	8	12	14
No. of Patents by Int'l joint	2	12	18	42

Note : Nationalities of joint inventors are GB and CA in 1980, CH, CA, GB, DE, SE, and CH in 1985.

GB, DE, KR, JP, FR, FI, IT, and IL in 1990. and TW, JP, IL, GB, DE, FR, CH, IT, CA, NL in 1995.

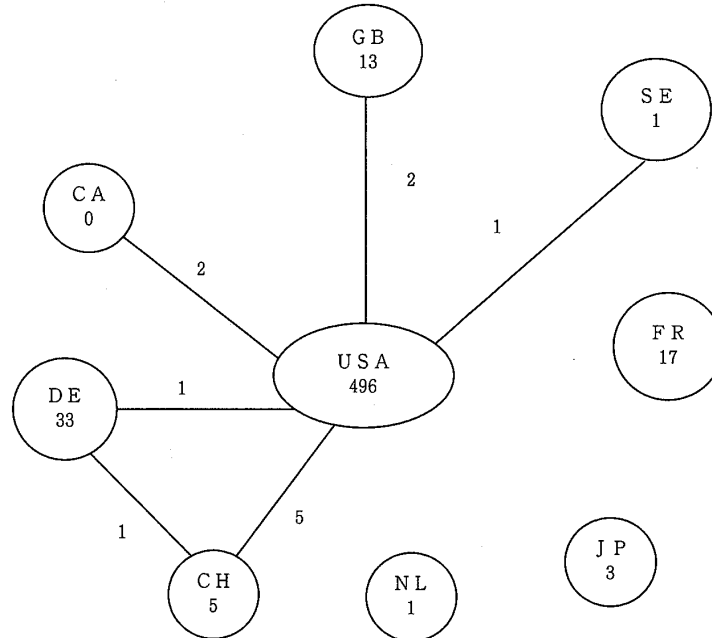
Source : [INPADOC] Searching

the U.S. in 1980, 1985, 1990 and 1995 by the nationalities of research institutes to which researchers who invented the patented technologies belonged.

As it is clear from the table, the numbers of U.S. patents invented by researchers at IBM institutes inside and outside the United States have both tended to grow, conse-

Figure 1

Global R&D System of IBM Corp. in 1985
 Number of Patents by IBM : 581
 By Nationality of Origin of Inventors (Number of US Patents)



CA : CANADA CH : Switzerland DE : Germany FR : France GB : UK
 JP : Japan NL : Netherlands SE : Sweden

Note 1 : Each straight line shows joint invention and the number beside the line shows that by joint inventions.
 Note 2 : Circle shows the number of patents invented by overseas IBM.

Source : Compiled from [INPADOC] searching.

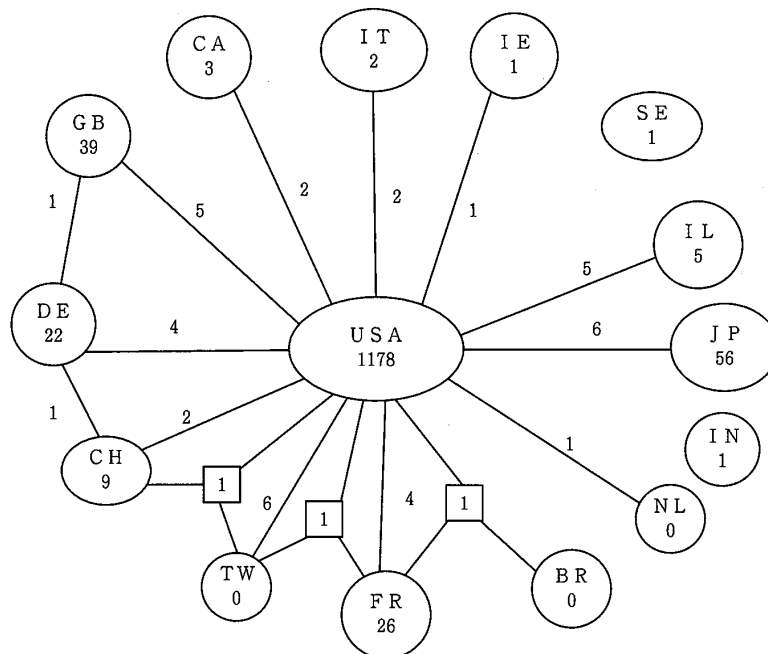
quently causing the total number of US patents granted to IBM to increase significantly. On the other hand, while the ratio of U.S. patents granted to technologies invented solely and jointly by IBM institutes overseas has remained almost the same, around 15 percent, the number of US patents attributable to the IBM overseas' inventions also increased steadily since 1985.

In order to further clarify these trends, the results are verified by putting them into diagram form with additional consideration given to the details of joint inventions. Figs. 1 and 2 are schematic diagrams showing the trend of internationalization and networking structure of R&D in this decade, based on the numbers of U.S. patents obtained by IBM's R&D facilities in different countries. The following five points could be pointed out from the table and these diagrams:

Firstly, as already examined above, a steady increase is observed in the number of patents granted to inventions developed by researchers who appear to belong to overseas

Figure 2

Global R&D System of IBM Corp. in 1995
 Number of US Patents by IBM : 1385
 By Nationality of Origin of Inventors : (Number of US Patents)



CA : CANADA CH : Switzerland DE : Germany FR : France GB : UK IL : Israel IN : India
 NL : Netherlands IT : Italy JP : Japan BR : Brazil IE : Ireland SE : Sweden TW : Taiwan

Note 1 : Each straight line shows joint invention, and the number beside the line and in the square shows that by joint inventions.

Note 2 : Circle shows the number of patents invented by overseas IBM.

Source : Cormpiled from [INPADOC] searching.

IBM research institutes. Secondly, the number of nationalities to which researchers who invented these U.S.-patented technologies belonged has also increased steadily. The number of such nationalities was four in 1980, seven in 1985, ten in 1990, and eleven in 1995, which is rather a sharp upward movement over the years. Thirdly, the number of joint inventions between inventors whose nationality is the U.S. and those with other nationalities has also increased, from 2, 11, 18 to 42, along with the number of nationalities of non-American researchers who were involved in IBM's joint inventions, which has shown an increase from 2, 5, 9 to 12⁴⁾. In consequence, the total number of overseas nationalities

4) The nationalities that involved in joint inventions with US IBM are UK and Canada in 1980, UK, Canada, Germany, Switzerland and Sweden in 1985, UK, Finland, Italy, Germany, France, Japan, Korea, Israel and Sweden in 1990, and Ireland, Italy, Canada, UK, Germany, Switzerland, Taiwan, France, Brazil, Netherlands, Japa and Israel in

has increased from 5, 8, and 12 to 14 over the same period.

Fourthly, the joint inventions between IBM overseas institutes⁵⁾ have appeared since 1985, in addition to the appearance of two new-type joint inventions characterized by the involvement of researchers with three different nationalities, that is, the U.S., Brazil and France for one and the U.S., France and Taiwan for the other.

The last notable point is that the number of U.S.-patented technologies which were invented by researchers belonging to domestic IBM research institutes has also been increasing in line with the number of U.S. patents granted to inventions by overseas IBM researchers.

From these five points, considering the fact that the ratio of U.S. patents granted to domestic IBM inventions to the total number of U.S. patents acquired by the entire IBM has not decreased, it would be reasonable to conclude that IBM has enhanced its R&D capabilities on a global basis by reinforcing its overseas R&D structure. Since IBM's domestic R&D capabilities have also been strengthened, it cannot be argued that its dependency on overseas IBM research institutes has increased. It would rather seem that the enhancement in the R&D networking with overseas IBM research institutes has in consequence led to the strengthening of domestic IBM research institutes in their R&D capabilities.

(b) Internationalization and networking of R&D activities of Philips N.V. - in the field of industrial technology

In this section I will throw light on the issues of how Philips.N.V., an European electric and electronics multinational company, has deployed its international R&D activities in the fields of industrial engineering in term of US patents while keeping international networking of R&D in mind.

Philips N.V. has main laboratories in 6 countries⁶⁾ : including Netherlands, Germany,

1995 respectively.

5) The nationalities of the joint inventions between IBM overseas are Germany and Switzerland in 1985, Germany, Switzerland and France in 1990, and Germany, UK and Switzerland in 1995.

6) The breakdown by the nationalities of the labs and the number of researchers are as follows:

Netherlands : 1,700(Philips Natuurkundig Laboratorium),
Germany : 400(Philips Forschungs Laboratorien)

United Kingdom, France, United States and Taiwan. The total number of researchers of the labs is 2,835 as of 1998. The numbers of US patents that Philips obtained are nearly at the same level, namely as is shown in Table 2, 527 in 1985 and 533 in 1995.

Of the 527 in 1985, the ratio attributed to overseas inventions that Netherlands has not been involved amounts to 49.8 percent. The main contributors of Philips overseas are US Philips with 70 US patents, followed by Germany with 64, UK with 57, France with 47, and Austria with 10 respectively. In addition, the number of international joint inventions between Netherlands nationalities and foreign nationalities is 19, accounting for 3.6 percent of all. In consequence, when taking these figures together, internationalization of R&D of Philips in 1985 in a broad sense, gets to 53.4 percent. On the other hand, though the ratio, in a narrow sense, in 1995 declined slightly to 45.5 percent, in a broad sense, this is still over 50 percent. As for the main overseas contributors in 1995 in terms of US patents, German Philips comes first with 66, followed by UK with 51, French with 47, US with 39 and Austrian with 20. Historically, Philips overseas subsidiaries have played critical R&D roles. The first programmed word processing typewriter, for example, was created by North American Philips, "smart cards" by its French subsidiary, teletext TV by its British subsidiary, stereo color TV by its Australian subsidiary: the list of local for local innovation in Philips is endless (Bartlett, C and Ghoshal, S [1990], pp. 229-230). As these cases indicate, its overseas R&D units seemed to have held autonomous and substantial R&D capabilities. However, the interesting point to be identified here is that the number of nationalities of researchers or engineers involved in the inventions excluding Netherlands has increased from 11 to 14 as are illustrated in Table 2, Figure 3 and 4.

In this regard, the results appear to indicate that while internationalization of R&D of Philips has stabilized over these years, it has evolved its R&D activities toward a more internationalized networking structure.

United Kingdom : 270(Philips Research Laboratories),
 France : 190(Laboratories d'Electricite Philips S.A.S)
 United States : 250(Philips Res.-USA),
 Taiwan : 25(Philips Innovation Center Taipei)

Since the years being examined are 1985 and 1995 respectively, Philips Innovation Center Taipei which was recently established may not have yet played an important role yet. It is to be noted that patentable inventions can not necessarily be made by researchers at labs, but by engineers at R&D facilities of divisions in the fields of electric & electronics technologies. Therefore, overseas R&D sections in Austria or Belgium seemed to play an important role.

Table 2 International R&D System of Philips N.V. and NEC Corp.
(By Nationality of Inventors : Number of US Patents in 1985 and 1995.)

	Philips N.V.		NEC Corp.	
	1985	1995	1985	1995
Total	527(100.0%)	533(100.0%)	180(100.0%)	1043(100.0%)
NLD* (or JPN*) : Domestic	246(46.7%)	266(49.0%)	179(99.4%)	1012(97.0%)
NLD (or JPN) & Overseas Joint	19(3.6%)	24(4.5%)	0	1(0.1%)
Overseas : Sole	258(49.0%)	238(44.6%)	1(0.6%)	30(2.9%)
Overseas & Overseas Joint	4(0.8%)	5(0.9%)	0	0
No. of Overseas Nat'lities*	10	12	1	2
No. of Other Overseas Nat'lities#	2	2	0	0
Total No of Nat'lities	12	14	1	2

Note : NLD and JPN stand for Netherlands and Japan respectively.

Number of Overseas Nat'lities* represents that of nationalities which invented domestically at these countries.

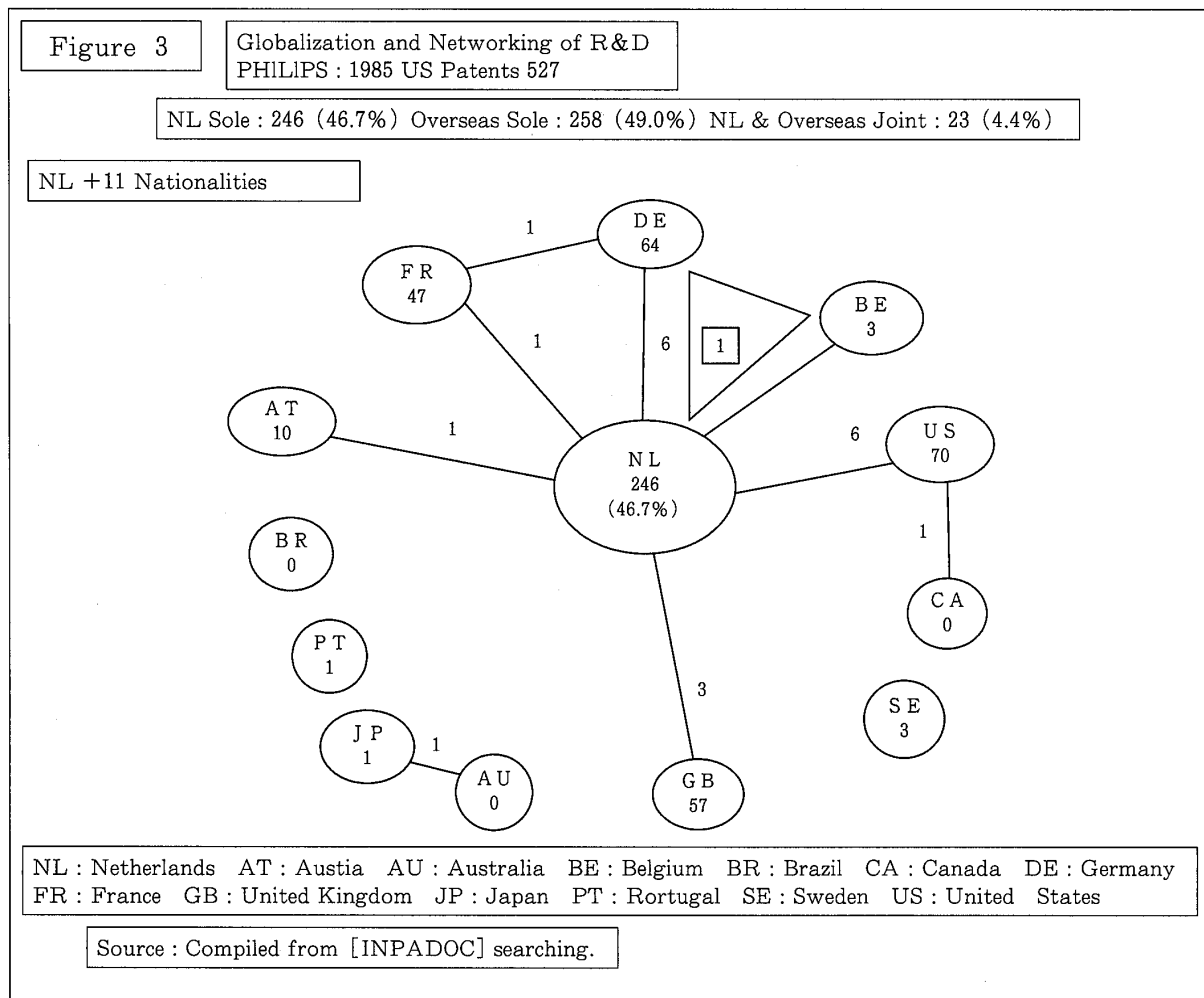
Number of Other Overseas Nat'lities# shows that of Nationalities involved in multilateral inventions without sole domestic inventions.

Source : Compiled from [INPADOC] searching.

(c) Internationalization and networking of R&D activities of NEC Corp. - in the field of industrial technology

As Table 2 reveals, of the 180 US patents that NEC obtained in 1985, the number attributed to overseas invention was only one which was invented by American researchers (or engineers), and the remaining 179 US patents were invented by its Japanese R&D staff members. Accordingly, the percentage ratio of the domestic inventions in Japan accounts for 99.4 percent of all. On the other hand, of 1,043 US patents that NEC acquired in 1995, the number by overseas inventions was 30 comprising of 29 American and one German, which still accounts for only 2.9 percent of the total. In addition to these overseas inventions, one international joint invention between Japanese and American researcher (or engineer) was found. The other remaining 1,012 US patents which accounts for 97.0 percent of all, were invented at NEC's domestic R&D facilities.

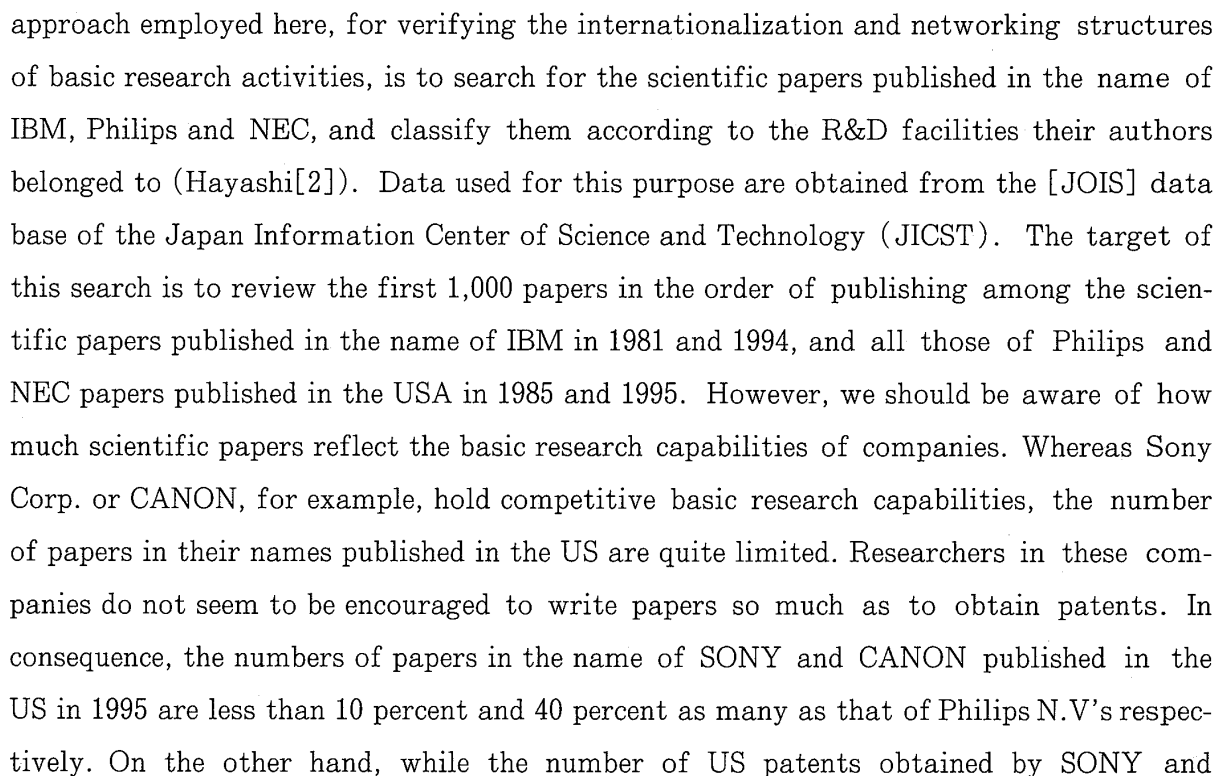
Therefore, when we examine the internationalization of NEC's R&D activities from the



point of patented technologies, the ratio is still well under five percent, although the absolute number is increasing. What is further to be noted is that overseas R&D activities of NEC are still virtually restricted only to the US. It indicates, therefore, that as far as patented technologies are concerned, although internationalization of R&D of NEC is steadily developing, it has not reached a stage of globalization. In this sense, it seems to be quite appropriate to conclude that NEC has concentrated its R&D activities at home in the fields of patented technologies.

3 Internationalization and networking of R&D activities at the level of basic research

While industrial engineering or industrial technologies, which mainly comprise the patentable technologies, are positioned fairly in the downstream along the flow of R&D activities, basic research is positioned in the upper stream of the process. The analytic



CANON in 1995 are 1.5 times and 2 times as many as that of Philips in the same year. It could not be concluded that the basic research capabilities of these Japanese companies are ten percent or forty percent as much as that of Philips'. However, although it implies some drawbacks, examining the trends of papers of companies in detail could provide us with such useful information as internationalization (and/or globalization) and networking of R&D activities of companies.

(a) Globalization and networking of R&D activities of IBM Corp. in the field of basic research

The number of scientific papers published by IBM researchers in the name of IBM in 1981 and 1994 are 4,045 and 1,902, respectively⁷⁾. Considering the fact that while the number of US patents IBM obtained has steadily increased, that of papers has by contrast declined. It seems to suggest that IBM Corp. has shifted its R&D strategies from the "R" oriented to the "D" orientation. Table 3 shows the results of searching through the first 1,000 papers published in the respective years and classifying them by nationalities of the research institutes the IBM authors belonged to. The reasons for limiting the search to scientific papers are to verify the quantitative share of each country resided by authoring IBM researchers and those who belong to other institutions participating in joint research with IBM at the level of basic research, and to determine the extent of internationalization and networking of IBM's R&D activities at the level of basic research.

Fig. 5 classifies the targeted 1,000 IBM papers published in 1981 by nationalities of institutes the authors belonged to, with the number of papers jointly authored with researchers at an institute in another country taken into account. As shown in this figure, the number of papers published by researchers belonging to IBM research institutes in the United States is 942, representing 94.2 percent of the 1,000 papers. Among them, however, 24 papers are authored jointly with an overseas institute other than IBM and 1 with an IBM institute overseas. After subtracting these, the total number of papers consisting of those published solely by IBM institutes in the U.S. and those jointly published by U.S. IBM institutes with non-IBM institutes in the United States is 917 (91.7 percent).

7) The numbers of papers published in the name of IBM based on a searching through JOIS for the respective years are as follows (the searching was conducted in July 1996):

1981 : 3,855, 1982 : 4,160, 1983 : 4,359, 1984 : 4,384, 1985 : 4,045,
 1986 : 3,436, 1987 : 1,904, 1988 : 2,146, 1989 : 2,259, 1990 : 2,411
 1991 : 2,327, 1992 : 2,200, 1993 : 1,899, 1994 : 1,902 (Hayashi[3])

Table 3 Globalization of R&D of IBM, Philips and NEC
(By number of papers in terms of authors of nationalities)

	IBM Corp.		Philips NV.		NEC Corp.	
	1981	1994	1985	1995	1985	1995
Total	1000 (100.0%)	1000 (100.0%)	234 (100.0%)	247 (100.0%)	196 (100.0%)	338 (100.0%)
Domestic Total	917 (91.7%)	734 (73.4%)	107 (45.7%)	122 (49.4%)	186 (94.9%)	220 (65.0%)
(Sole : Domestic)	856	405	88	103	166	190
(Joint : Domestic)	61	329	19	19	20	30
Domestic & Overseas Joint Total	25 (2.5%)	111 (11.1%)	20 (8.5%)	33 (13.4%)	3 (1.5%)	22 (6.5%)
A (Intrafirm Int'l Joint)	1	8	8	9	0	5
B (Int'l Joint with Non-IBM/ Philips/NEC Overseas Inst.)	24	103	12	24	3	17
Overseas Total	58 (5.8%)	155 (15.5%)	107 (45.7%)	92 (37.2%)	7 (3.6%)	96 (28.4%)
C (Sole : Overseas	40	70	82	52	7	37
D (Joint with Local)	11	48	16	28	0	45
E (Overseas & Overseas Joint)	3	36	8	10	0	14
F (Overseas & Non-IBM/Philips/ NEC Domestic Inst.)	3	n.a	0	1	0	0
G (Intrafirm : Overseas & Overseas)	1	1	1	1	0	0
Internationalization (1) = A+B+C+D+E+F+G/1000	0.084	0.266	0.542	0.506	0.051	0.349
Internationalization (2) = C+D+E+F+G/1000	0.06	0.155	0.457	0.372	0.036	0.284
Total Number of Nat'lities Overseas'Inst.	15	22	8	17	2	14
Number of Nat'lities of IBM/Philips/ NEC Overseas'Inst. (3)	12	12	6	7	1	3
Number of Nat'lities of Non-IBM/ Philips/NEC Overseas'Inst. (4)	10	18	5	17	1	13

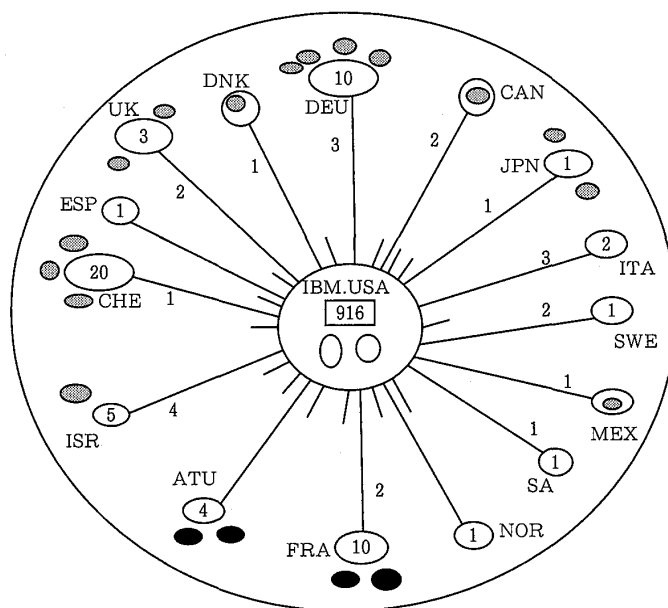
Note : (1)~(4) ; See Fig. 5~10 and Table 4.

Source: [JOIS] Searching

Figure 5

Outline of the Global R&D System of IBM Corp.
Number of Papers in the Name of IBM Corp. in 1981

IBM USA : 916
IBM USA & Overseas Non-IBM institutions Joint : 23
IBM USA & IBM Germany : 1
IBM Overseas : 59
IBM Switzerland & IBM Germany : 1



Note (1) Each Number in the circles shows the number of articles by IBM itself.

Note (2) Each number beside the straight lines shows joint articles with non-IBM overseas R&D institutions.

Note (3) Spores around IBM USA show Non-IBM R&D institutions in the US.

Note (4) ● shows overseas R&D institutions apart from IBM.

ATU : Austria
CAN : Canada
CHE : Switzerland

DEU : Germany
DNK : Denmark
ESP : Spain

FRA : France
ISR : Israel
ITA : Italy

JPN : Japan
MEX : Mexico
NOR : Norway

SA : South Africa
SWE : Sweden
UK : United Kingdom

Source : Compiled from JOIS

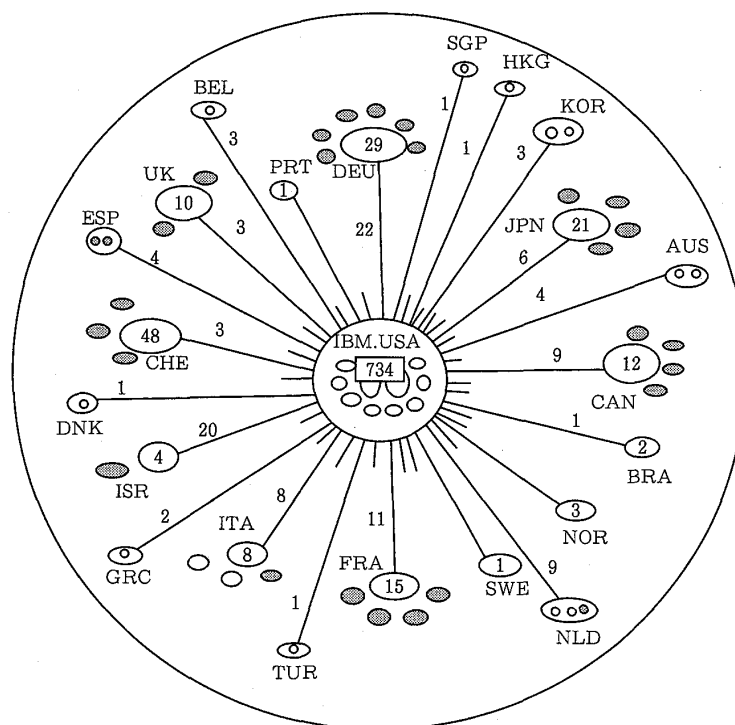
By contrast, IBM papers published by researchers belonging to overseas IBM institutes, including those papers jointly published by them with overseas non-IBM institutes and those jointly authored between IBM research institutes located in different countries outside the U.S., totals 60, accounting for merely 6.0 percent of the total. The nationalities of these IBM institutes are Switzerland, Germany, France, Israel, Austria, England, Italy, South Africa, Spain, Sweden, Norway and Japan (12 nationalities).

Fig. 6 shows a classification by the same method of the first 1,000 papers published in 1994 in the name of IBM. What is to be indicated from a comparison between figure 5 and Fig. 6 are the following four points. The first point is a relative decline in the total number of papers solely published by U.S. IBM institutes and jointly published by

Figure 6

Outline of the Global R&D System of IBM Corp.
Number of Papers in the Name of IBM in 1994

IBM USA : 734 IBM USA & Overseas Non-IBM : 103 IBM Overseas & Overseas Non IBM : 155



Note (1) Each Number in the circles shows the number of articles by IBM itself.

Note (2) Each number beside the straight lines shows joint articles with non-IBM overseas R&D organizations.

Note (3) Spores around IBM USA show R&D institutions in the US.

Note (4) ● shows overseas R&D organizations apart from IBM

DEU : Germany	UK : United Kingdom	SWE : Sweden	TUR : Turkey	SGP : Singapore	ESP : Spain
JPN : Japan	ISR : Israel	NOR : Norway	NLD : Holland	HKG : Hongkong	DNK : Denmark
CAN : Canada	ITA : Italy	PRT : Portugal	AUS : Australia	CHE : Switzerland	FRA : France
BRA : Brazil	GRC : Greece	KOR : Korea	BEL : Belgium		

them with U.S. non-IBM institutes to 734⁸⁾, i.e., 73.4 percent. Secondly, that the number of papers jointly published by U.S. IBM institutes with non-IBM overseas institutes based on international joint research activities increased sharply from 24 in 1981 to 103 in 1994. Thirdly, that an increase in the number of papers published in the name of IBM institutes outside the U.S. (total number of papers which are written solely by overseas IBM, joint papers by overseas IBM and overseas non-IBM, and joint papers between non-U.S. IBM in

8) The majority of joint research partners is from universities in the US totaling 88. When examining other remaining papers excluded in this research, the number of universities which participated in the joint research with IBM should further increase.

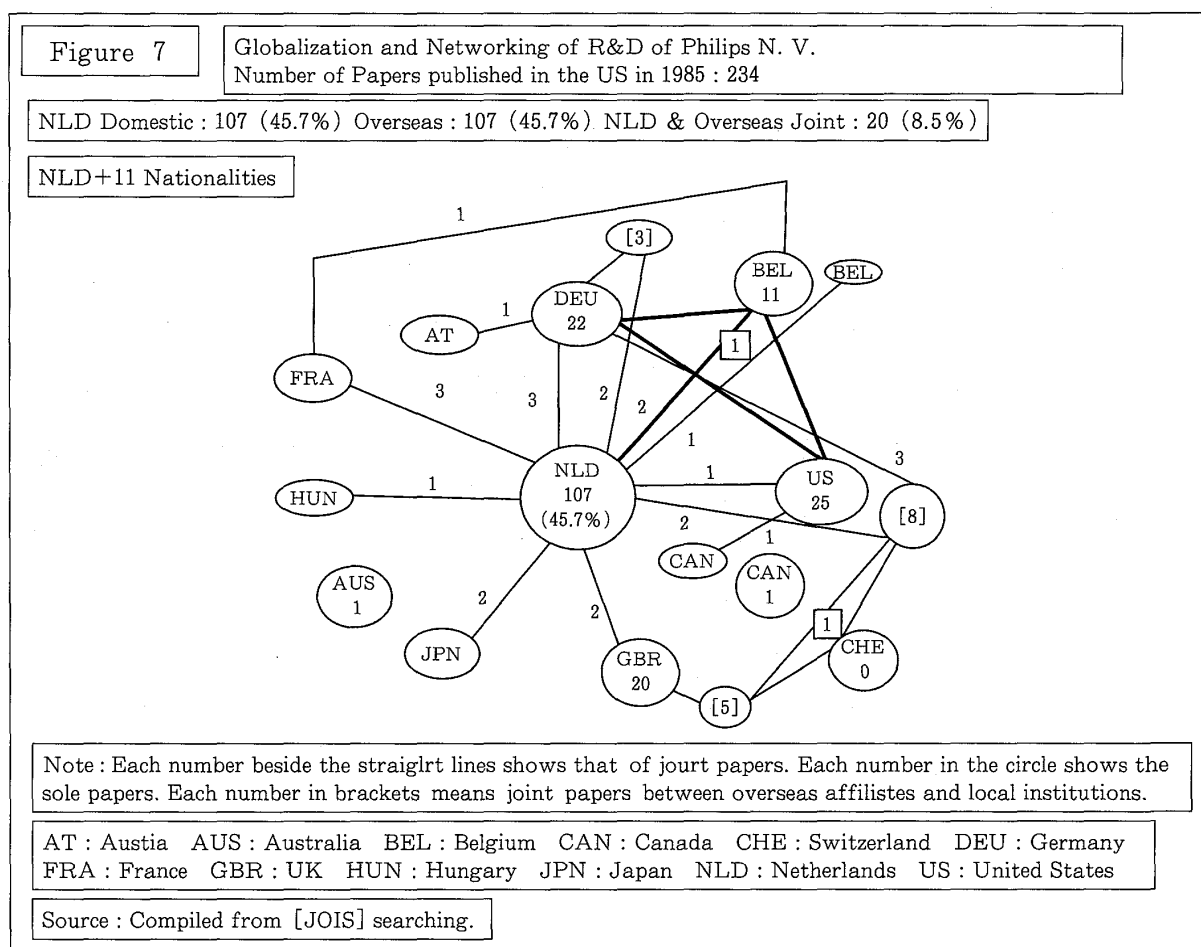
different countries) accounted for 155 out of 1,000, showing a significant rise from 5.8 percent in 1981 to approx. 15.5 percent in 1994. And finally, although the nationalities of research institutes that researchers who published papers in 1994 in the name of IBM belonged to a range across 12 nationalities, which is as many as those in 1981, the number of nationalities of overseas non-IBM institutes which joint authors of the target papers belonged to, after excluding the nationalities of overseas IBM institutes that published joint papers in 1994, increased from 10 in 1981 to 18, including East Asian countries.

From the four points mentioned above, it seems likely that IBM Corp. has rationalized her basic research activities on a global scale. However, the company has strategically augmented the extent of internationalization of IBM's R&D activities keeping a global networking of its international R&D activities in mind.

(b) Internationalization and networking of R&D of Philips N.V. in the field of basic research

As Table 3, Figure 7 and 8 show, the total number of papers published in the US that overall researchers of Philips were involved increased slightly from 234 in 1985 to 247 in 1995. Interestingly, publications by researchers who belong to Philips Netherlands, excluding the international joint ones, increased from 107 (45.7%) to 122 (49.4%) over the same period. This illustrates, on the contrary, that the ratio of internationalization of R&D in the basic research fields has decreased in a broad sense from 54.2 percent to 50.6 percent in this decade. It is important to note here that the ratio in a narrow sense, which excludes Philips Netherlands, decreased from 45.7 percent in 1985 to 37.2 percent in 1995. The biggest reason why the ratio of internationalization of R&D in a broad sense has increased is due to the fact that the number of sole domestic papers has increased by 15, and that of sole papers by overseas Philips institutions has decreased by 30 respectively in this decade. On the other side, joint research between Philips Netherlands and non-Philips overseas institutions, and between Philips overseas and non-Philips overseas local institutions, have increased from 12 to 24 and from 16 to 28 respectively over the same period.

When examining the number of these joint papers in order to throw further light on the networking of R&D, it is notable that universities play key roles of Philips' networking activities. The total number of universities involved in joint papers, excluding duplica-



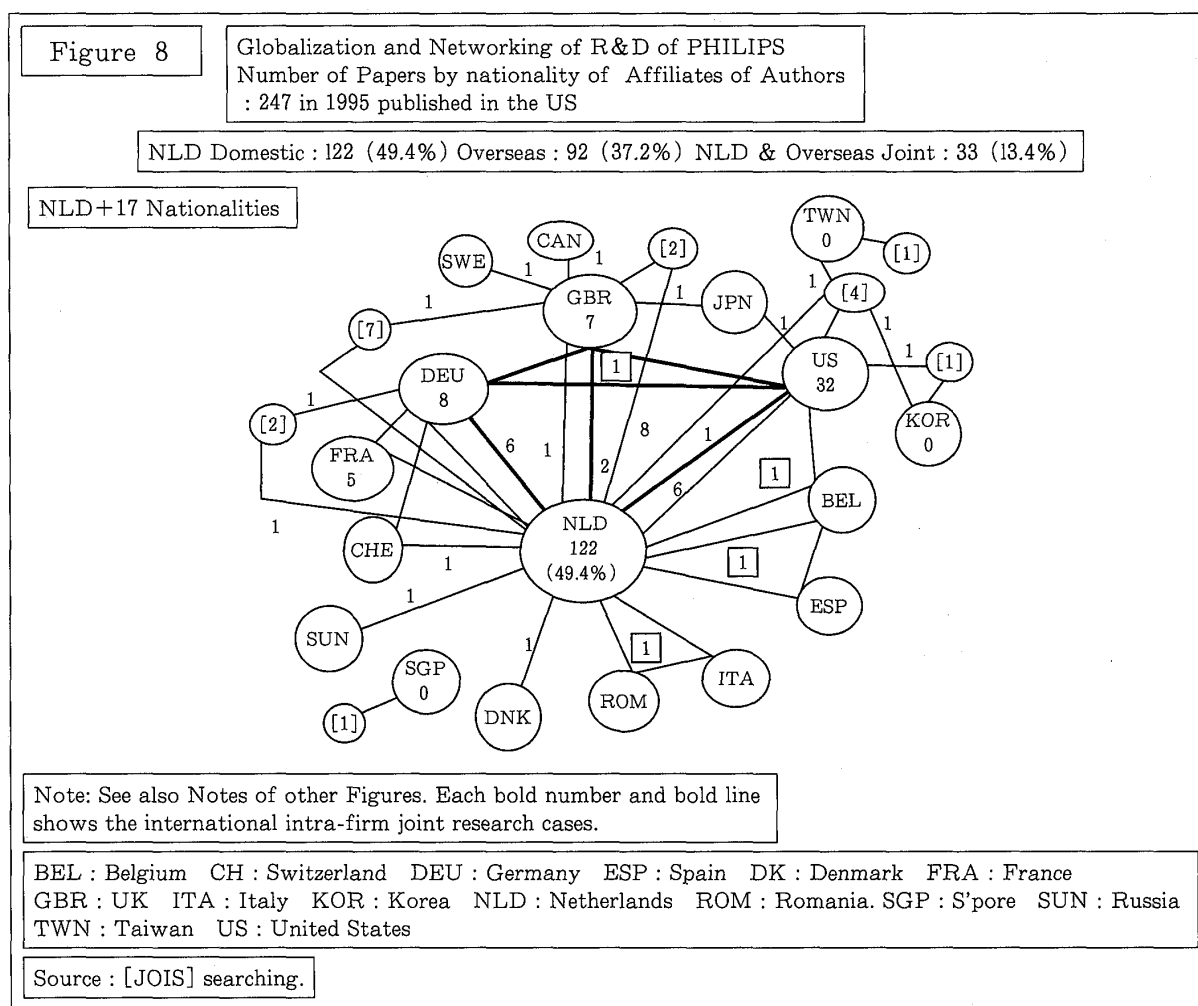
tions, published in 1995 in the US amounts to 48⁹⁾.

These universities are comprised of 14 US universities, followed by 7 Dutch and British universities, 6 German, 2 Belgian, Italian, Korean and Taiwan, and 1 French, Denmark, Russian, Japanese, S'porean and Romanian universities respectively. In addition to the universities, researchers of 28 companies and laboratories inside and outside the Netherlands participated in joint papers, of which Dutch companies and labs account for only 14 percent with 4. It is interesting to note that 15 US companies and labs¹⁰⁾ are involved accounting for more than 50 percent.

Finally, as the figures provide some overviews of international networking of R&D of Philips N.V., not only the nationalities involved in the joint research papers apart from

9) Among the 48 universities, Eindhoven University (Netherlands) contributed the most with 9 joint papers, followed by Delft University (Netherlands) with 6, Nijmegen University (Netherlands) with 3 and all other universities with less than 2. .

10) AT&T (Bell Lab) is the most active in the joint papers with 7, followed by General Instruments, Zenith and David Sarnoff Research Center with 3 respectively.



Netherlands have increased in number¹¹⁾ and variety, but also the number of cases of a more diversified international joint research have become prominent¹²⁾.

It could well be summarized that in terms of the number and joint research structures of papers, the basic research capabilities of Philips N.V. would seem to have been maintained through internationalization and a further network oriented structures of R&D.

(c) Internationalization and networking of R&D of NEC Corp. in the field of basic research¹³⁾

11) The number of overseas nationalities involved in the sole and joint research papers augmented from 8 nationalities in 1985 to 17 in 1995 (see also Table 4).

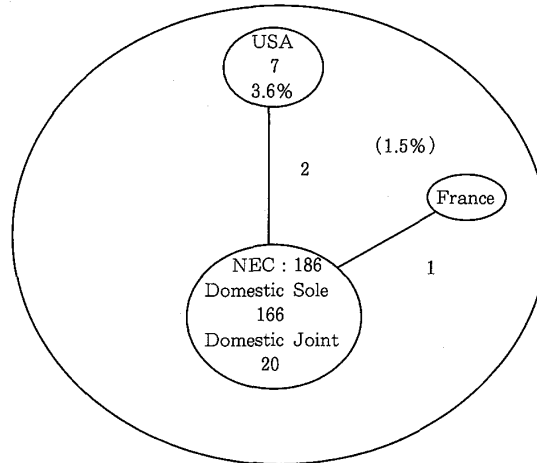
12) The number of overseas nationalities participating in the joint papers among overseas institutions was 7 in 1985 and 10 in 1995. However, as the former individual cases were not identified, they are not illustrated in Figure 9.

13) R&D fields and locations of NEC Corp. are as follows:

Figure 9

Internationalisation of R&D of NEC Corp.
Number of Papers by Nationalities of Authors
(196 Papers in the Name of NEC published in the US in 1985)

JPN+ 2 Nationalities



Note(1) : Each Number in the circles shows the number of articles by NEC itself.

Note(2) : Each number beside the straight lines shows joint articles with non-NEC overseas R & D organizations, which are Univ. of California and Columbia Univ in the US. and the national lab in France.

Source : Compiled from [JOIS].

As are indicated in Table 3 and Figure 9, the number of papers in the name of NEC published in the US in 1985 is 196, of which those by its overseas institutes is seven (:3.6 percent), those by international joint research is three (:1.5 percent), and those by Japanese researchers is 186 (:94.9 percent). As for the papers credited to the overseas institutes, the authors were researchers who belonged to NEC's US R&D institutes. On the

(1) Domestic R&D Locations:

- 1 Central Research Lab(Computers and Communications, established in 1975, Kawasaki)
- 2 Tsukuba Research Lab. (New Concepts, New Materials, New devices, established in 1989, Tsukuba)
- 3 Sagamihara Research Lab.(Key Devices, established in 1987, Sagamihara)
- 4 Kansai Electronics Lab.(Compound semiconductor devices, established in 1991, Ohts)
- 5 Kansai Research Lab.(Human Interface Field, established in 1990, Osaka)

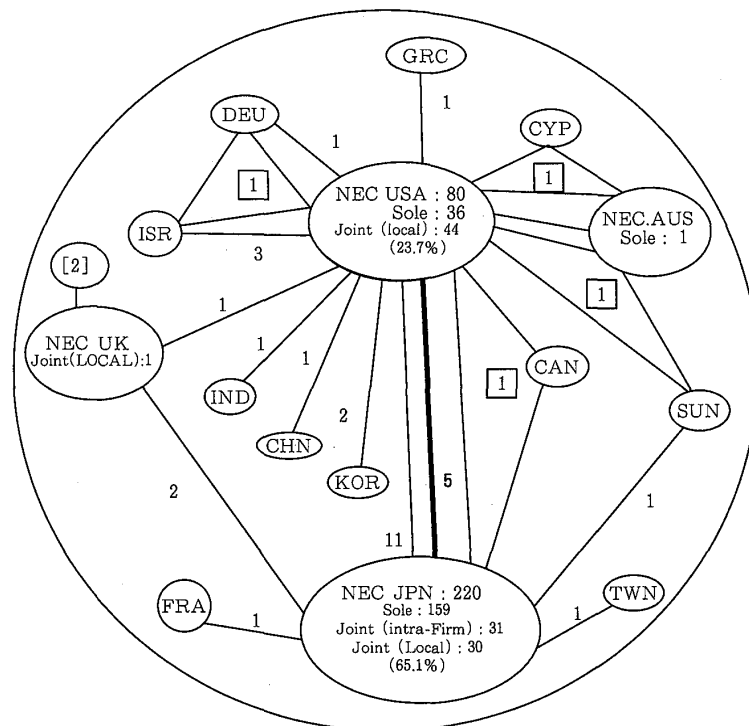
(2) Overseas R&D Locations:

- 1 NEC Research Institute(Basic Res. in New Materials, Devices Mechanisms of Human Logic & Thinking, established in 1989, New Jersey, Princeton)
- 2 C&C Lab NEC USA(C&C System Technologies, established in 1991, Princeton in 1995, San Jose)
- 3 C&C Research Lab NEC Europe (C&C Technologies, in 1994, Sankt Augustin, in 1995, Berlin, Germany)

Figure 10

Internationalization and Networking of R&D of NEC Corp.
338 Papers published in the USA in 1995

NEC JAPAN : 220 (65.1%) NEC Overseas : 82 (24.3%) Int'l Joint : 36 (10.7%)



Note (1) : Each Number in the circle shows the number of sole papers.

Note (2) : Each number beside the straight line shows joint papers with non-NEC overseas R&D organizations.

Note (3) : Each number in the square shows the joint papers among three different nationalities.

Source : Compiled from JOIS searching

other side, as is demonstrated in Figure 10, the number of papers in the name of NEC in 1995 is 338; of which sole papers by researchers who belong to NEC's US institutes is 36, joint papers with US local institutions is 45, and overseas joint research papers between NEC's US institutes and other overseas research institutes excluding Japan is 14. Accordingly, the number of papers by NEC's overseas research institutes is 96 which accounts for 28.4 percent of all, which represents a internationalization of R&D in a narrow sense.

In addition, the number of papers by international joint research between NEC Japan's R&D institutes and overseas non-NEC research institutes is 17 accounting for 3.9 percent of all, and international intra-firm joint research papers between NEC USA and NEC Japan appeared with 5. Therefore, the number of papers by its international R&D activities, in a broad sense, amounts to 118 which is 34.9 percent of all which is even higher than that of IBM's in 1994.

What is to keep in mind next is that, as are illustrated in these figures, not only are NEC's R&D activities themselves being internationalized, but also its international joint research networking is being drastically established. In addition to the fact that the number of overseas nationalities involved has drastically augmented from 2 to 14 in this decade, Figure 10 also reveals an interesting feature that the extent of networking of US R&D activities of NEC is apparently higher than that of Japan's in terms of the domestic and international joint research. More than 50 percent of 80 locally written papers of NEC's US R&D units have been carried out in collaboration with 17 US Universities¹⁴⁾, 3 companies¹⁵⁾ and 3 scientific institutions¹⁶⁾; while merely less than 15 percent of 220 papers by Japan's R&D units have been conducted in collaboration with 15 local Universities¹⁷⁾, 7 companies and 1 other institution. This suggests that NEC Japan has pursued its R&D projects mainly at its in-house R&D units without enhancing its domestic R&D network with other non-NEC scientific institutions at home. It indicates, on the contrary, that it has enhanced its international R&D networks centering on US R&D units instead of Japan's local non-NEC R&D organizations.

If this reflects the fact that basic research capabilities of the Japanese universities are relatively weaker than those of US and Europeans (Hayashi [4]), it could be its strategic policies that NEC puts more emphasis on overseas R&D institutions than domestic ones in its international networking of R&D activities.

Internationalization of R&D of NEC Corp. seems to be, in a relative term, more advanced than expected. Though in terms of basic research, it can hardly be said to be globalized.

It could be concluded, therefore, that innovative activities of its industrial technologies have been mainly undertaken domestically, integrating the fruits at the basic science

14) As far as the papers published in 1995 in the US are concerned, researchers of Princeton University and Rutgers University contributed the most with 6 respectively, follow by Syracuse Univ. with 5, Univ. of California with 3, MIT, Carnegie Mellon, Columbia, Texas M&A, and Cornell University with 2 respectively, and 8 other universities with 1.

15) AT&T Bell Lab. comes first with 9, followed by IBM and BURC Inc. with 1 respectively.

16) They are comprised of Brook Haven National Lab., David Surnoff Res. Center and Joseph Henry Lab.

17) These 15 Japanese Universities are comprised of Osaka Univ. with 5, Tokyo Univ. with 4, Tsukuba Univ., Saitama Univ. and Tokyo Metropolitan Univ. with 2 respectively and 10 other universities with one.

level that were created at (and jointly with) its overseas basic research activities.

5 Conclusion

This paper has mainly verified the extent of internationalization and networking of R&D activities of three companies at the level of industrial technology in the fields of industrial engineering, and at the level of basic research by searching through US patents obtained by them and scientific papers published in the name of these companies.

According to the results of searching through the patents, the fact that they acquired an increasing number of patents by technologies newly invented by their overseas R&D facilities is clear evidence that the development capabilities of their overseas R&D facilities at the level of industrial technology are growing. Also as a result of searching through the targeted papers, it is viably pointed out that their networking for joint research with their own overseas research institutes, overseas universities, companies and laboratories is steadily progressing and that, at the basic research level, the achievements of overseas research institutes are increasing overall. These tendencies are clearly found in the case of IBM Corp. These trends can be observed not only from the increase in the number of IBM's R&D facilities overseas that published papers and those that invented patented technologies, but also from the progress in the globalization of IBM's joint research network with a wide variety of R&D institutes overseas. These trends further suggest the following two possibilities. The first possibility is that IBM may have succeeded to a sufficient extent in establishing a system to subsume achievements gained through the internationally distributed technological development capabilities into its domestic system, thereby leveraging the relatively decreasing technological development capabilities of U.S. IBM alone. The system thus established has allowed IBM to ensure relative enhancement of its enterprise-wide technological development capabilities on a global scale by addressing strategically the relative decrease in the technological development capabilities held by U.S. IBM alone. The second possibility is that the establishment of global R&D structure by IBM may have led to the construction of a global transfer system for newly created technology information that allows R&D achievements to be transferred instantaneously to overseas R&D operations on a global scale via the global intra-firm R&D structure.

In the case of Philips N.V. the extents of internationalization of R&D in terms of both patented technologies and basic research which demonstrate the highest among three

multinationals investigated here have both tended to be stabilized around 45 - 50 percent over this decade. It is interesting to note, however, that the extents of networking of its R&D activities in terms of these technologies have steadily been enhanced so that the company seems to have made extensive use of overseas R&D resources and maintained its R&D competitiveness.

Finally, whereas the extent of internationalization of NEC's R&D activities in terms of patented technologies has stayed under 5 percent over this decade, basic research has been drastically increased over the same period. Regarding to the extent of its networking of R&D in terms of patented technologies it does not seem likely that NEC has enhanced its overseas R&D capabilities in the fields of patentable technologies. By contrast in terms of basic research, it has prominently progressed centering on US. It seems likely that the company seeks to strengthen its basic R&D capabilities by tapping into the fundamental research expertise in foreign R&D sites centering on the US.

What is appropriate to all the three multinationals is that, as is shown in Table 4, the numbers of nationalities of the scientific institutions involved in R&D activities of the companies have augmented without any exceptions in terms of US patents and scientific papers. It seems most likely that globalization of competition requires the multinationals to further recognize the importance of precompetitive basic research. In this sense, it seems to be strategically inevitable for multinationals to internationalize their R&D in order to collaborate with overseas local scientific institutions (see, also Pearce [1992-96]).

In summary, as made evident by searching through scientific papers, R&D activities of such Japanese company as NEC appear to be evolving towards internationalization and networking at a much higher ratio than other such multinationals as IBM or Philips in terms of basic research. Finally, it could hardly be denied that enhancing global intra-firm R&D structures of these companies in turn implies that the more the structures play the role of subsuming the achievements of R&D activities by overseas R&D facilities, the more these newly produced technologies disperse globally and vice versa.

From the findings above, although our sample is too small to draw any firm conclusions, I would dare to conclude that current trends in the globalization and networking of R&D activities by multi-national enterprises are moving toward the establishment of an integrated global-scale system for centralizing and dispersing technology production. Thus, as the multi-polar technological development structure manifests itself increasingly, the tactical importance of networking and globalization of R&D activities grows in inter-

Table 4 Number of Nationalities of Institutions involved in US Patents and Scientific Papers Published in the US in the Name of Each Three MNCs in the respective Yeas.

	IBM		Philips		NEC	
	1980('81)	1995('94)	1985	1995	1985	1995
(Australia)		[#]	# [#]			[#]
(Austria)	[#]		#	#		
(Belgium)		[#]	# [#]	# [#]		
(Brazil)		# [#]	#			
(Canada)	# [#]	# [#]	# [#]	# [#]		[#]
(China)						[#]
(Cyprus)						[#]
(Denmak)	[#]	[#]		# [#]		
(France)	# [#]	# [#]	# [#]	# [#]	[#]	[#]
(Gemany)	# [#]	# [#]	# [#]	# [#]		# [#]
(Greece)		[#]				[#]
(Hongkong)		[#]		#		
(India)		#				[#]
(Ireland)		#				
(Israel)	[#]	# [#]				[#]
(Italy)	[#]	# [#]		[#]		
(Japan)	[#]	# [#]	# [#]	# [#]	# [#]	# [#]
(Korea)		[#]		[#]		[#]
(Mexico)	[#]					
(Netherlands)		# [#]	# [#]	# [#]		
(Norway)	[#]	[#]				
(Portugal)		[#]	#			
(Romania)				[#]		
(Russia)				[#]		[#]
(Singapore)		[#]		# [#]		
(South Africa)	[#]					
(Spain)	[#]	[#]		# [#]		
(Sweden)	[#]	# [#]	#	[#]		
(Switzerlnd)	# [#]	# [#]		# [#]		
(Taiwan)		#		# [#]		[#]
(Turkey)		[#]				
(UK)	# [#]	# [#]	# [#]	# [#]		[#]
(United States)	# [#]	# [#]	# [#]	# [#]	# [#]	# [#]
Total Number of Nat'lities	22	38	22	33	5	18
No.of Nat'lities (Patent) #	6	15	13	15	2	3
No.of Nat'lities (Paper) (#)	16	23	9	18	3	15

Note : # shows the number of nationalities involved in patented invention, and (#) shows that of nationalities involved in research papers.

In the case of IBM, the years of patent issue are 1980 and '95, and those of papers are 1981 and '94.

Source : Compiled from [INPADOC] and [JOIS] searching.

national business strategies.

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