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R&D Activities and Technical Information Flow in Japanese Electronic Corporations

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ABSTRACT

R&D Activities and Technical Information Flow in Japanese Electronic Corporations

by Ulrike Görtzen

The paper analyzes R&D-activities of Japanese electronic corporations in the context of the firm's performance for the period 1986 to 1996. Compared to the R&D-expenditures-to-sales ratio the profit-on-sales ratio is remarkably low for the whole industry. This stresses the problems which the electrical machinery is facing in a time of growing diversification, extremely high costs for new developments and stiff competition with non-patent-protected products.

For the analyze data of the Kaisha Database of the Social Science Center Berlin were used. The sample consists of 31 Japanese corporations of the electrical machinery industry. In order to find out how corporations of the sample differ according to their performance and R&D-structure, the sample was divided in successful and less successful corporations. A production function of the Cobb-Douglas Type was estimated for both groups and two periods. As input factors capital, labor and R&D-expenditures were used. In a further step the number of board members with R&D background on the board was integrated as a proxy for the importance of an effective information structure.

Finally the structural characteristics of the two groups were analyzed due to R&D organization, R&D planning and an international approach to R&D in order to find further explanations for the different performances of the two groups.

ZUSAMMENFASSUNG

FuE-Aktivitäten und technischer Informationsfluß in japanischen Elektrounternehmen

Die Studie untersucht die FuE-Aktivitäten von japanischen Elektrounternehmen in Zusammenhang mit dem Erfolg der Unternehmen im Zeitraum von 1986 bis 1996. Auffällig ist, daß die Umsatzrendite verglichen mit den FuE-Ausgaben in Prozent vom Umsatz bei allen Unternehmen erstaunlich niedrig ist. Das verdeutlicht die Probleme, mit denen diese Branche in einer Zeit zunehmender Diversifikation, extrem hoher Kosten für neue Produktentwicklungen und hartem Wettbewerb im Bereich von nicht patentierten Produkten zu kämpfen hat.

Die Untersuchung wurde mit Daten aus der Kaisha-Datenbank am Wissenschaftszentrum Berlin durchgeführt. Das Sample besteht aus 31 japanischen Unternehmen der Elektrotechnischen Industrie. Um Unterschiede beim wirtschaftlichen Erfolg als auch bei den FuE-Aktivitäten zwischen den Unternehmen heraus zu arbeiten, wurde das Sample in erfolgreiche und weniger erfolgreiche Unternehmen unterteilt. Für beide Gruppen wurde eine Produktionsfunktion vom Cobb-Douglas Typ für zwei Perioden geschätzt. Als Inputfaktoren wurden Kapital, Arbeit und FuE-Ausgaben verwendet. In einem zweiten Schritt wurde die Anzahl der Vorstandsmitglieder mit nachhaltigen Erfahrungen im FuE-Bereich als Indikator für die Bedeutung von effizienten Informationsstrukturen integriert.

Abschließend wurden strukturelle Merkmale der beiden Gruppen untersucht in Hinblick auf die FuE-Organisation, FuE-Planung als auch die FuE-Aktivitäten im Ausland, um weitere Erklärungen für das unterschiedliche Abschneiden der beiden Gruppen zu finden.

1. Introduction

1.1. Competitive strength of the Japanese Electronic Industry

This paper provides a brief overview of the range and volume of R&D activities in Japan's industries during the period of 1986 to 1996 focusing on the performance of the electrical machinery industry. How important was research during the bubble economy? In which way did the industry react to the prolonged recession in the early 1990s regarding research activities? Are companies showing a tendency to reduce their R&D expenditure in an effort to cut costs and improve their short-term management efficiency as the recession and the growing severity of the economic crisis following the bursting of the economic bubble continue to chip away at their operating margins?

It is not just since the *Tamagochi* was born that Japanese electronic companies are considered to be innovative and highly competitive. Among the ten leading data processing corporations in 1996 four are Japanese and the 2nd to 4th rank among the semiconductor manufactureres worldwide belong to Japanese corporations.[1] Nevertheless there are certain fields on which the competitive strength has weakened. Even though Japanese electronic firms did develop computer systems and software, they were not able to push through these standards on international markets. Regarding the world-wide success of Microsoft and other U.S. computer and software makers, concern is raised that the gap between the U.S. and Japan in high technology is growing. Comparing the priorities Japan puts on research in the information & electronics fields with those of the U.S. and Europe, an evaluation by specialists in respective fields resulted in the appraisal that Japan's level came down between 1991 - 1995, although compared to Europe Japan is still winning.[2]

This paper will point out the range of innovative capabilities within the Japanese electrical machinery industry consisting of companies engaged in the Information Technology (IT), communication business as well as in the development of consumer electronic products and electrical machinery. The paper tries to point out the course of R&D activities in connection with economic success. What R&D volume and R&D structure do companies with an outstanding performance show? In order to find out the emphasis corporations put on R&D we will estimate a production function with Capital, R&D-expenditures, Labor and a proxy for information flow as input factors. The analysis suggests that firms with high R&D spending in combination with R&D-structures that do support efficient information flows are more competitive. Furthermore it seems necessary

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1 See http://www.fujitsu.co.jp/hypertext/About_fujitsu/Gyouseki/rank96.html.

2 The comparison was made for 1991, 1994 and 1995 for basic research and 1994 and 1995 for applied research. Kozo (1996), p. 44.

that corporations focus their research acitivities on special fields. This implies that the firm's overall research laboratories are coordinated by a research strategy developed and communicated at a central operating group.

The empirical investigation uses data drawn from the Kaisha-Database of the Social Science Research Center Berlin (WZB). The data base consists of information collected from Annual Reports according to Stock Exchange Law (Yûka shôken hôkoku sho) of 104 companies listed at the first section of the stock market in Tôkyô. They belong to the pharmaceutical (11), chemical (31), machinery (27), shipbuilding (3) and electrical machinery branches (32).[3]

1.2. R&D activities in Japan

The 1970s and 1980s show a distinct increase of industrial R&D spending. During the period between 1972 and 1995, the nominal sum increased more than eightfold. In 1995 Japan spend Yen 14,408.2 billion on R&D, nearly 71.3 % of this volume was raised by the industrial sector. Regarding the expenditures in percent of sales, a rapid growth has taken place likewise. In the 1990s Japanese companies did reach the international standard by using 2.8 % of their sales volume on R&D.

The growth rate of the overall R&D-expenditure roughly follows the growth rate of the general domestic product (Fig. 1). During the bubble economy there was a steep rise followed by a deep decline after the bursting of the bubble at the beginning of the 1990s. As a result, the stronger emphasis of companies on basic research which was perceptible during the bubble weakened. In 1995 the share of basic research declined to 6.6 % of total industrial R&D-activities (1992: 6.9 %). In contrast to this tendency the government strengthened its activities in this area. Its share rose from 16.5 % in 1992 to 20.5 % in 1995.[4]

The government spent about 0.5 % of GDP (1995: 0.59 %) on R&D on average, which is only half of what governments in the U.S. or European countries spent. The quantitative share of Japanese public expenditures of overall R&D amounted to 22.9 % in 1995.[5] The government funds are mainly used for research cooperations. Government

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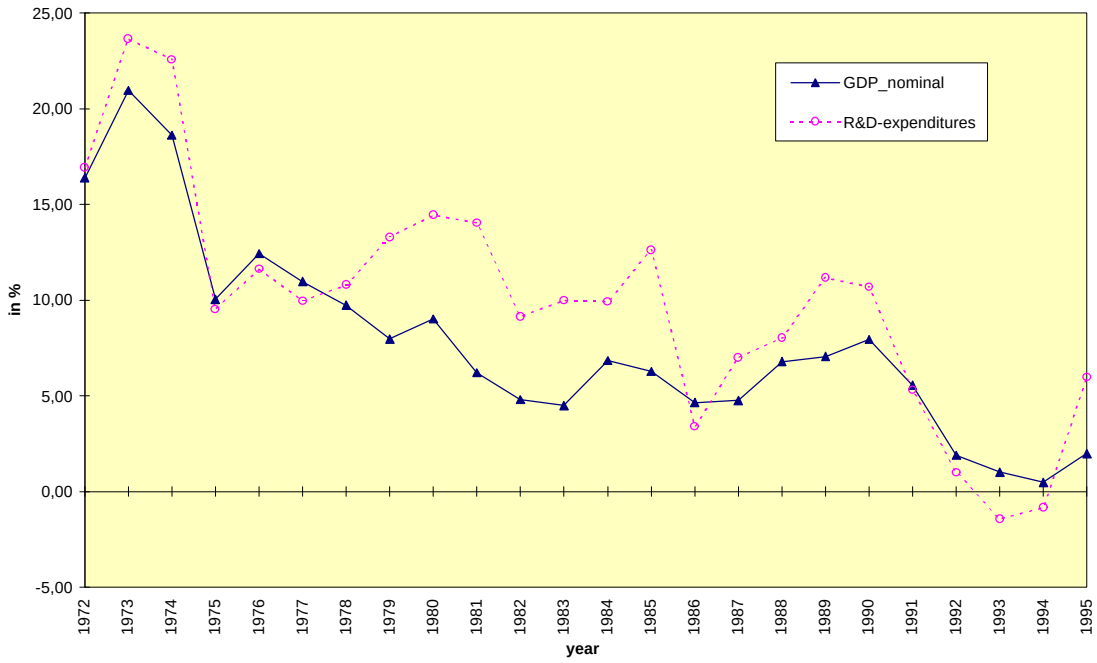
3 This division is based on the Japanese Company Handbook, Spring 1997.

4 For the next five years further efforts in the basic research field are planned. On July 2, 1996 the basic plan for science and technology was approved by the Cabinet. The plan aims at the promotion of R&D for expanding frontiers for industry and for solving global issues and problems concerning peoples`s lives and the enhancement on basic research. See http://www.sta.go.jp/kihonkeikaku/basicplan.html.

5 U.S.: 35.0 %; Germany: 37.1 %; France: 44.3 %; GB: 33.3 %. Kagaku gijutsu hakushô (1997), p. 414-425.

promotion and support has played an important role for a large number of joint research projects by private companies, particularly in the inauguration stages.[6] By initiating joint research projects, the government tries to accelerate the dissemination of technical knowledge.

Figure 1: Change of GDP growth and R&D-expenditures (growth over previous year)
Source: KKC 1997: appendix, p. 14, KGC 1997, p. 414



This is also done by distributing detailed information about scientific, economic and social developments in White Books and by publishing a Delphi Report.[7]

Direct support of research projects initiated by corporations is an exception. Only 1.4 % of the industrial research projects were financed by public funds in 1993 whereas in Germany the share amounted to 9.2 % in the same year.[8]

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6 A quantitative analysis of joint research projects enumerates 156 projects carried out in the 70s and 80s in which leading enterprises of the electrical machinery inudstry were engaged. See Shirai/Kodama (1989).

7 Hemmert points out that the systematic institutionalization of such dissemination mechanism represents the true core of the Japanese technological policy. Hemmert (1996), p. 256.

8 The share is even higher in the United States (19.7 %) and France (18.3 %). OECD (1995).

2. Empirical Analysis

2.1. Description of Data

R&D activity can be quantitatively captured by its input or output. In this analysis R&D-expenditure is used as input factor. The annual reports of the companies do frequently contain information about the volume of R&D-expenditures either in the income statement or in the R&D status report. Nevertheless, because the definition of R&D expenditures in the accounting standards can be interpreted in different ways, the statements cannot be compared.[9] Some firms for example include labor costs for R&D employees, some do not. Therefore all data for R&D-expenditures was selected from the Japan Company Handbook (Spring or autumn edition 1985 - 1997). These particulars do not include R&D activities of subsidiaries, and therefore are non-consolidated.[10] For Matsushita Kotobuki Electronic Industries R&D-expenditures were not available. Financial data like sales, fixed assets, operating profits, license fees and royality payments as well as the number of employees have been extracted from the Kaisha-Database of the WZB. The number of patents and utility models are not continuously reported by all companies. Nevertheless the available data has been collected.

Finding indicators for the mechanism of technical information flow is limited by available information. As a first approach the composition of the boards as well as the organizational structures were analyzed. This information was gathered from the annual reports of the companies. All firms start publishing an organizational structure since 1987/88. Additional information from web pages of the companies, for example about research labs abroad, have been added.

The composition of the board has been examined with regard to board members with R&D background. In the annual reports, the board members are introduced with a short curriculum vitae including the main positions they held in the past. All members of the board who held a senior position in a research or development division during their career have been counted for the fiscal years 1986, 1989, 1992, 1994 and 1996. Moreover we had a look at the major at the universities and last of all at the number of license agreements between firms.

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9 See Nixon (1996) and Akashi (1996), p.22-26.

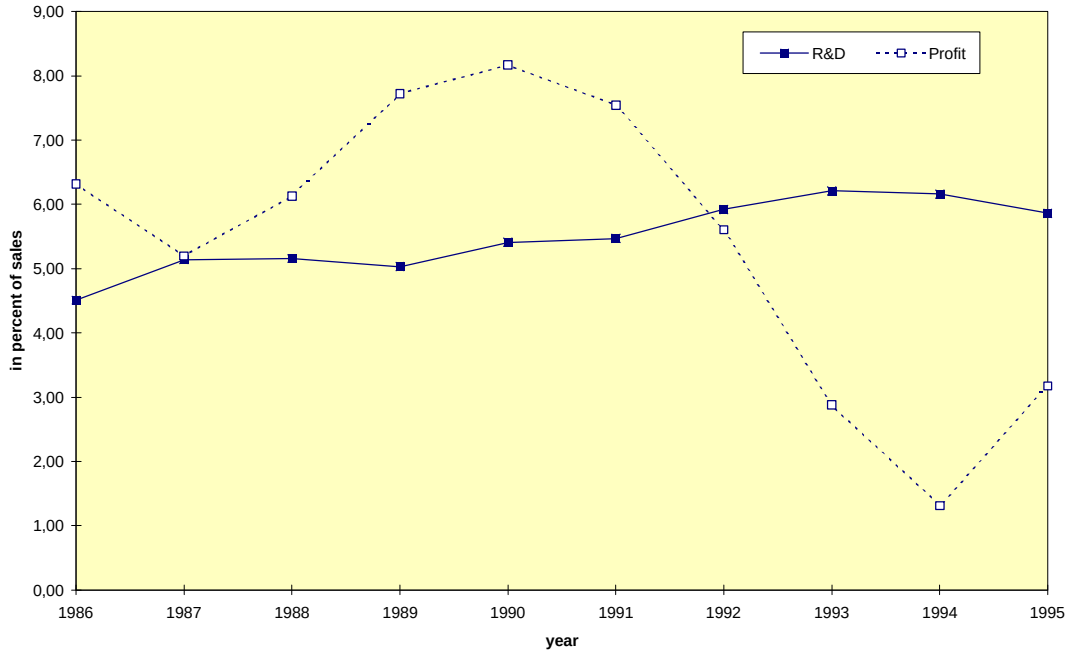
10 There are two exceptions in the sample: For Sony Corporation and Matsushita Electric Industrial only consolidated R&D expenditures were available.

2.2. R&D activities and business performance – four industries compared

A comparison of the operating-profit-on-sales-ratio (profit ratio) with the R&D-expenditures-on-sales-ratio (R&D ratio) of all companies comprised in the WZB-Database, demonstrates the effects of the bursting of the bubble in 1991. The mean profit ratio declines about seven percentage points from nearly 8 % in 1990 to about 1 % in 1994. Surprisingly, in contrast to this development the growth of R&D ratio only shows a slowdown (Fig. 2). This indicates that most companies did not reduce their R&D budgets despite of the recession.

Three of the five reasons Okimoto/Nishi (1994) give for the stable patterns of R&D expenditures at Japanese companies seem to be of special importance: „(1) high degree of diversification and vertical integration; (2) the staying power of intra-industry standards (*yoko narabi*); and (3) long-term employment practices“.

Figure 2: **Growth rate of operating-profit-on-sales and R&D-expenditures-on-sales**
(Mean value of all corporations in the WZB-Database)
Source: Kaisha-Database, own calculation



Larger corporations with a high level of diversification can shift their revenues from one product division to the R&D activities of a different area. Therefore R&D budgets do not depend on sales of single products. *Yoko narabi* means that firms observe the activities of competitors of comparable size and prestige and adjust their activities accordingly. The Japanese system of long-term employment is a factor of special weight for the relatively constant level of R&D expenditures. The number of researchers cannot easily be reduced in times of economic slowdown so that salary outlays have to be paid

anyway.[11] Nevertheless an increasing tendency of *shukkô* (transferees) can also be observed within the research staff.[12]

In an inter-industry comparison the electrical machinery industry shows the second highest R&D ratio following the pharmaceutical industry (see A1, Appendix). Nevertheless, that does not lead to a comparable innovative output (in a sense of marketable products and operating profits). The mean profit- and R&D ratio of pharmaceutical, chemical and machinery firms contained in the WZB-Database are compared with the mean values of the electrical machinery sample (see Figure 3). Compared to other industries, the electrical machinery industry shows a low profit ratio in relation to the R&D ratio. In contrast to the other industries, the curve shape of the profit ratio never runs above the curve shape of the R&D ratio. This stresses the problems which the electrical machinery is facing in a time of growing diversification, extremely high costs for new developments and stiff competition with non-patent-protected products.[13]

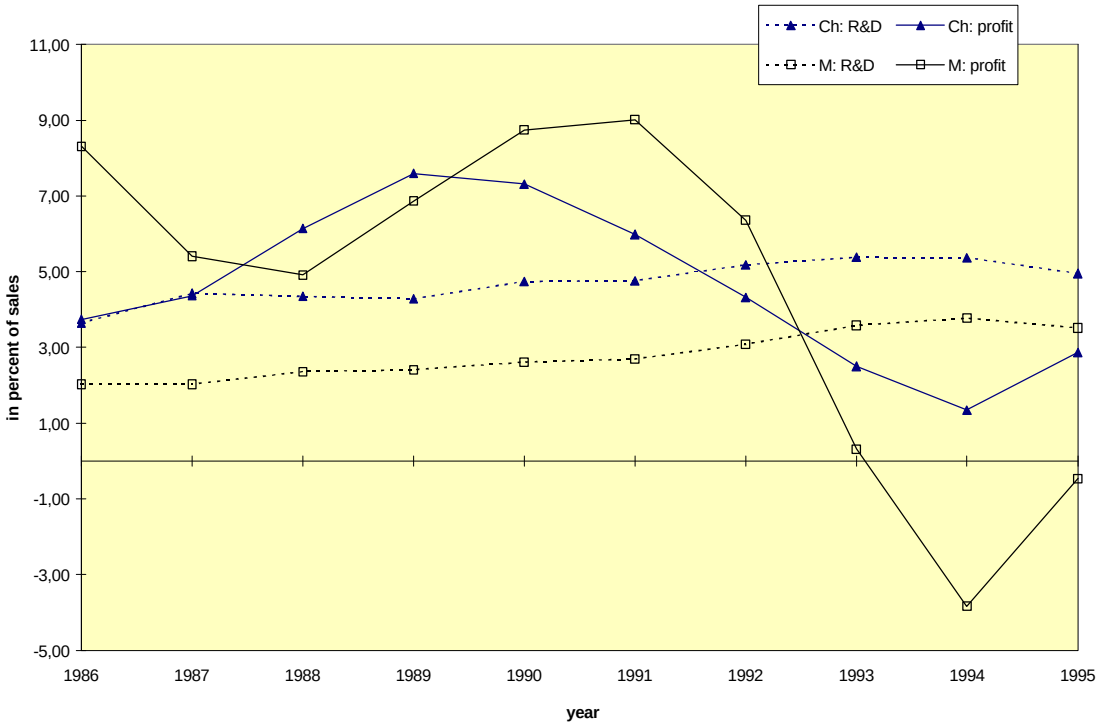
Figure 3a: Change of profit ratio and R&D ratio in the pharmaceutical and electrical machinery industries (mean values)
Source: Kaisha-Database, own calculation

11 See Okimoto/Nishi (1994), p.182-185.

12 For more information about the phenomenom of *shukkô* see Zobel 1997, WZB discussion paper, FS IV 97-44.

13 Kodama points out that the growing specialisation forces companies to hire more research staff. Furthermore investments in R&D equipment commonly seen in Very Large-Scale Integration (VLSI) plants are a major item in the R&D budgets. Kodama (1997), p. 23.

Figure 3b: Change of profit ratio and R&D ratio in the chemical and machinery industries (mean values)
Source: Kaisha-Database, own calculation



The survival of companies in the electrical machinery industry depends decisively on their innovative capability. This industry is characterized by short innovation cycles so that companies must invest continuously in future products. Kodama (1991) calls this kind of investment "surf-riding". Corporations have to ride the next innovation wave as long as they want to stay in the market.[14] An example often cited in this context is the development of consecutive DRAM (Dynamic Random Access Memory) generations.[15]

Above all an extremely strong international competition keeps the profit margins low and tends to push up the R&D-expenditures. An explanation for the different performance of the pharmaceutical industry, which has an even higher R&D ratio, might be the greater difficulties for competitors to develop slightly different substances in order to pass the patent protection.

Therefore the conclusion that the electrical machinery industry has to strengthen the efficiency of its R&D-activities in general cannot be drawn from the curve shapes of the profit-on-sales ratio and the R&D-to-sales ratio. The following analysis will show that this group consists of efficient and less efficient companies. Moreover there are grounds for the assumption that the less efficient companies would have a higher profit-on-sales ratio if they strengthened their R&D-activities.

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14 See Kodama (1991), p. 7-8.

15 See e.g. Okimoto/Nishi (1994), p. 196-197.

2.3. Electrical Machinery Industry - R&D and its impact on performance

As mentioned above the electrical machinery industry shows the highest R&D ratio after the pharmaceutical industry in Japan. Because of a growing intensity of competition, companies are tackling R&D with the aim of raising their overall capability, not only of their own major products, but also in the diversification of their business operations, by lifting their technological capabilities over a wide area, from basic research to product development.[16] The sample consists of 31 corporations of which about 20 originated in the consumer electronic products and communication equipment fields. Most of them already expanded their core business to the IT (Information Technology) and telecommunication sectors or are on their way to catch up. Among the former, the ten leading Japanese producers of semiconductors can be found of which NEC, Toshiba and Hitachi have the 2nd to 4th ranks worldwide among semiconductor manufacturers (1995).[17] The remaining 11 companies of the sample are producers of electrical machinery like Fuji Electric, Makita Corporation and Yaskawa Electric Corporation. Their research activities range from the development of power equipment, scientific instruments, traffic measuring equipment to office automation and the applications of robots.

The 31 corporations of the electrical machinery industry chosen for the survey account for about a quarter of the total amount of industrial R&D spending in Japan.[18] The R&D to sales ratio of Japan's huge electronic firms clusters closely within a narrow band. In 1996, Sony Corporation showed the highest R&D-ratio by using 13.3 % of its sales for R&D-activities (see A2, Appendix). The other major players are not far behind, Matsushita Communication Industrial and Fujitsu Ltd. spent more than 10 %, Hitachi Ltd., Matsushita Electric Industrial, Sharp and NEC employ about 9 % of their sales on R&D. As mentioned above it is the *yoko narabi* nature of budget making, which ensures that the R&D-expenditures at the company level tend to remain fairly stable.[19] Although the electrical machinery industry as a whole shows a remarkably high R&D ratio, there are also corporations with lower R&D ratio. The opposite end of the sample is represented by Makita (3 %), Fujitsu General (3,68 %) and Teac (3,72 %) in 1996. Without an exception the firms with a low R&D ratio are of smaller size (according to sales volume). The mean of the R&D ratio of the sample adds up to 7.1 % in 1996. The

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16 Hitachi was the first establishing a laboratory for basic research in 1985. See Westney 1994, p. 165.

17 See http://www.fujitsu.co.jp/hypertext/About_fujitsu/Gyouseki/rank96.html. On leading position is the American Intel corporation.

18 This is not a big surprise though the whole Japanese electrical machinery industry unites about a third of the whole Japanese industrial R&D expenses (1993: 33,7 %). See OECD 1995.

19 *Yoko narabi* means that firms observe the activities of competitors of comparable size and prestige and adjust their activities accordingly. Okimoto/Nishi 1994, p. 183

sample was divided into two groups using the profit (after tax) per employee ratio as an indicator for business performance (see Table 1).

Table 1: The two groups: Mean values of profit per employee and operating profit on sales between 1986 and 1995
Source: Kaisha-Database, own calculation

Top group	**Profit per employee**	**Operating profit on sales**
	(in 1,000 Yen)	(in %)
Makita Corporation	2277.19	13.38
Matsushita Electric Industrial Co., Ltd.	2256.58	4.66
Sony Corporation	2215.68	4.27
Kokusai Electric Co., Ltd.	1904.79	6.36
Hitachi Koki Co.,Ltd.	1700.38	9.46
Sharp Corporation	1507.26	5.38
Kyushu Matsushita Electric	1421.54	7.06
Matsushita Communication Ind. Co., Ltd.	1271.96	5.52
Pioneer Electronic Corporation	1185.36	5.00
Omron Corporation	1104.71	4.55
NEC Corporation	1060.23	3.04
Hitachi Ltd.	1002.36	4.01
Sanken Electric Company, Ltd.	849.97	3.59
Japan Radio Co., Ltd.	849.02	5.19
Toshiba Ltd.	712.81	3.22
Bottom group		
Fujitsu Ltd.	695.44	2.97
Meidensha Electric Mfg.Co., Ltd.	622.05	3.01
Matsushita Refrigeration Company	619.66	5.27
Osaki Electric Co., Ltd.	616.16	6.55
Mitsubishi Electric Corporation	588.19	2.84
Sanyo Electric	575.60	2.59
Fuji Electric	538.77	2.26
Aiwa Co., Ltd.	479.21	1.00
Kenwood Corporation	381.39	1.94
Oki Electric Industry Company, Ltd.	281.31	1.36
Yaskawa Electric Corporation	239.46	1.80
Victor Company of Japan, Ltd.	87.63	1.04
Tokyo Electric Co., Ltd. (TEC)	-219.99	1.05
Fujitsu General Ltd.	-606.84	-2.57
Teac Corporation	-933.77	0.13
Clarion Company	-1049.71	0.26

A means of profit per employee was computed for each of the 31 companies of the sample for the period between 1986 and 1995. The profit of the top group ranges from Y0.71 mio. to Y2.3 mio. The operating profits in relation to sales of this group are considerably higher as well.[20]

The top group consists of electronic giants like Matsushita Electric, Toshiba, NEC and Sony as well as smaller corporations like Makita, Omron and Kokusai Electric. A high R&D ratio links all firms of the top group with two big exceptions, Sanken Electric Company and Makita Corporation, which belong to the firms with the lowest R&D to sales ratio of the whole sample. Apart from Fujitsu Ltd. and Sanyo Electric all firms of the bottom group spend less than seven percent of their sales for R&D activities (see appendix, A2).

The differences between profit and R&D ratio of the two groups (see Fig. 3) are impressive. The curves run at completely different levels. But even the successful group has higher R&D-expenditures than profits on sales except for the years 1989 to 1991, which are the last years of the bubble economy if the time-lag due to company reporting procedures is considered.

This supports the thesis that high profits can only be gained by intensive R&D activities. However the costs for R&D are skyrocketing and seem to have lost the connection to profits. As mentioned above this is due to strong international competition and high costs for R&D facilities. But not only the level but also the relation of profits and R&D expenditures of the bottom group shows big differences compared to the top group. This results in the conclusion that this group does not get the same profit out of its R&D-input.

In order to find more detailed explanations for the different performance of the two groups, the R&D-strategy and -structure of the involved corporations have been examined. The mean scale and performance is summed up in Table 2.

The firms of the successful group have remarkably higher sales revenues as well as higher levels of R&D-expenditures. In the research laboratories of the first group a lot more R&D- staff is working and the budget they can spend is more than five times bigger than in the second group.

The most striking difference concerns the income under license agreements and the license fees. The successful group earns much more than it pays whereas the balance of the less successful group is negative. The latter is amazing if the number of license agreements is included.

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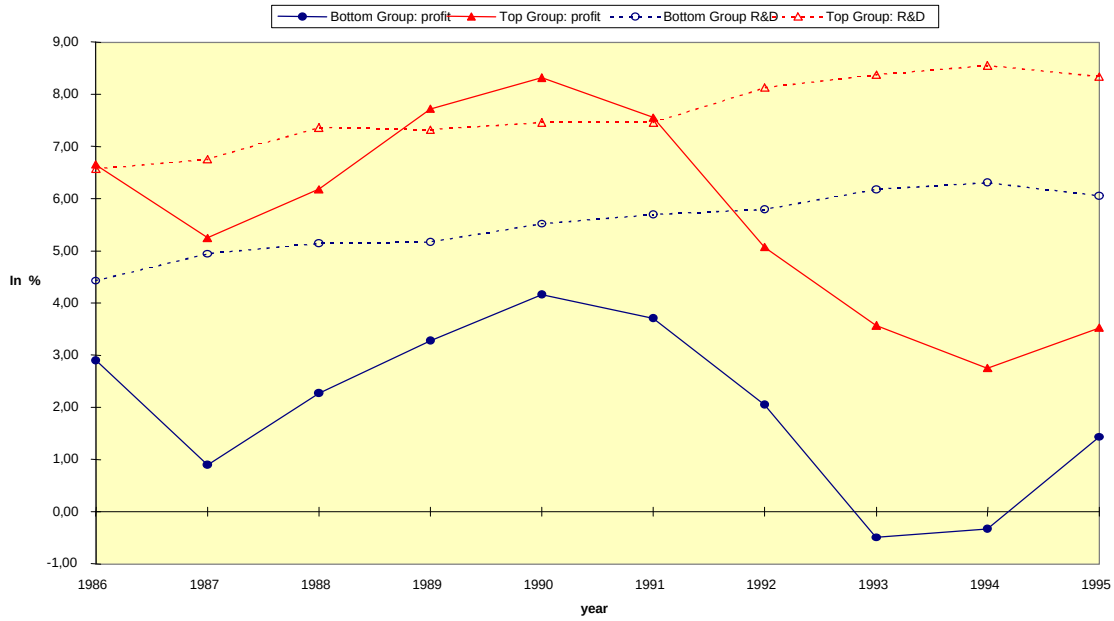
[20] The Spearman correlation coefficient is 0.857 (significant at the 0.01 level).

Figure 4: R&D-ratio and profit-ratio - the two groups compared
Source: Kaisha-Database, own calculation



This leads to the hypothesis that the innovation level on which the licenses are based, is not very high, so only relatively low license fees can be charged. The number of patents is not representative although there is reason for an advantage of the top group.

Even if a company does not strive for innovative leadership it has to carry out a certain level of research in order to maintain the ability for dialogue.[21] It seems to be a matter of fact that long-term success in this field is not possible without intensive research activities.

Therefore it can be assumed that companies of this line of business, with a high success ratio over a ten year period, do in fact place higher priority on R&D-activities. Moreover as international competition increased it has to be assumed that the emphasis on R&D activities intensified. At any rate, there is no company within the sample which does not conduct any research activities at all.

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21 Albach points out that firms that only imitate will sooner or later lose their competence. In the pharmaceutical industry this is called „losing the ability for dialogue“. Albach (1986), p. 50.

Table 2: Performance of the two groups
Source: Kaisha-Database, own calculation

	Top Group		Bottom Group	
Mean value	**1986 - 1990**	**1991 - 1996**	**1986 - 1990**	**1991 – 1996**
Sales (in bio. Yen)	1036.014	1333.059	461.526	575.992
R&D-expenditures (in bio. Yen)	84.228	124.659	31.119	45.627
R&D in % of sales	8.13 %	9.35 %	6.74 %	7.92 %
R&D-employees (1996)*		6,464		2,151
R&D-expenditures per employee in 1,000 Yen (1996)*		88,210		16,975
License fees paid (in bio. Yen)	2.508	4.331	2.176	5.560
License fees received (in bio.Yen)	7.113	9.113	0.264	1.136
Number of granted license agreements	6	3	4	20
Number of acquired license agreements	11	10	8	9
Fees received per granted license agreement (in mio. Yen)	1.185	3.037	0.066	0.057
Fees paid per acquired license agreement (in mio. Yen)	0.228	0.433	0.272	0.617
Number of patents / utility models**		597		163

* Data of 10 corporations (6 in the top group, 4 in the bottom group)[22]

** These data are reported by five companies (Top Group: Makita, Hitachi Koki and Hitachi Ltd.; Bottom Group: Meidensha Electric, Fuji Electric)

In order to find a measure for the importance of R&D for the companies' output, we estimated a production function of the Cobb-Douglas Type.[23] Besides the employment of capital and labor we used R&D-spending as a third input factor. The production function can be written as follows:

$X = a_o C^{\alpha} L^{\beta} RD^{\gamma}, \qquad \alpha + \beta + \gamma = 1$

with: C: Capital; L: Labor; RD: R&D-expenditures, a_o: parameter.

[22] Only four corporations, Fuji Electric, Hitachi Ltd., Kokusai Electric and Teac publish the number of their R&D employees in the annual report. These data were completed by information gained in interviews with NEC, Matsushita Electric, Sony, Aiwa, Sanyo and Omron carried out by Rita Zobel (Research fellow, WZB) in Oct.-Nov. 1997.

[23] I would like to thank Jiangping Yang for carrying out the estimation .

The complete results, which are significant, are presented in Table 3. The estimation was conducted for the whole group as well as separately for the two groups. [24] In a second step we analyzed the changes within the whole sample by looking at two different periods. Two tendencies are predominant:

(1) In the second period the importance of R&D has increased in a very distinct way within the whole sample,
(2) The estimated value for R&D is more than three times bigger for the top group.

Table 3: Results of the first estimation

	Sample (31)	**Sample (31)**	**Sample (31)**	**Top Group**	**Bottom Group**
	1986 - 1996	**1986 - 1990**	**1991 - 1996**	**1986 - 1996**	**1986 - 1996**
Capital:	0,53078	0,57853	0,40513	0,46209	0,82576
	(16,9)	(15,92)	(9,597)	(13,32)	(12,66)
Labor	0,27329	0,28253	0,27705	0,29468	0,10035
	(9,96)	(9,432)	(7,457)	(8,972)	(1,839)
R&D	0,19592	0,13894	0,31782	0,24323	0,07389
	(11,75)	(6,998)	(14,62)	(13,71)	(2,142)
Const.:	3,5206	3,4801	3,8703	3,8384	1,3874
	(11,96)	(10,75)	(9,545)	(10,93)	(2,369)
R-Square:	0,9831	0,9880	0,9869	0,9898	0,9599
Durbin-Watson:	1,7926	1,6576	1,7536	1,7860	1,815
(....) T-Ratio					

The results point out that R&D activities have been a very important factor for the top group during the whole period, whereas the bottom group did not show this emphasis. Due to the estimation results there is an increase in significance for the estimated R&D value of the whole group in the second period. The estimated value for labor is nearly the same for both periods so that the increasing influence of R&D on the output is accompanied by a decreasing influence of capital in the second period. The results support the thesis that the influence of knowledge (represented by R&D expenditures and partly by the number of employees) on the ouptut of the firms has increased.

[24] For the random disturbance autocorrelation of first order has been assumed.

In a second step we added a variable which should represent the quality of strategic R&D decisions in the company. In Japan most directors of the board are full-time and insiders. In contrast to the U.S. the majority comes from production and technology departments, followed by marketing and export. Odagiri/Goto (1993) stated the advantages of this background as follows:

„The better knowledge and experience of Japanese managers in production / R&D provide them with a better understanding of the potentials and limitations of R&D projects, more accurate evaluation of the outcomes from R&D, and more favorable general attitude toward R&D. Similarly, their better knowledge and experience in sales / marketing provide them with a keen understanding of what kinds of products are in demand in the markets. These familiarities of Japanese managers with technological seeds and market needs are particularly valuable in technologically rapidly changing markets.“[25]

In addition, it has to be considered that Japanese managers have normally spent their whole carreer in the same corporation. This provides them with a profound knowledge of technological capabilities and innovative potentials of their firms. For this analysis the number of directors on the board with an R&D background has been counted for selected years. This factor has to be viewed as technical knowledge that shapes the strategic decision of the corporation and influences the output in the end. The production function can be written as follows:

$X = a_o C^{\alpha} L^{\beta} RD^{\gamma} RBM^{\delta}$

with: C: Capital; L: Labor; RD: R&D-expenditures;
RBM: Board members with research background.

The results are summarized in Table 4. The influence of the „technical knowledge“ is increasing over time. This might indicate that corporations re-think not only their R&D budgets but also their R&D strategies and structures. Unfortunately it was not possible to estimate this production function for the two groups separately due to the relatively small input factor RBM and the size of the sample. Looking at the absolute figures we can see that the top group shows a higher percentage of board members with research background during the whole period (See Fig. 4).

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25 See Odagiri / Goto (1993), p. 106-107.

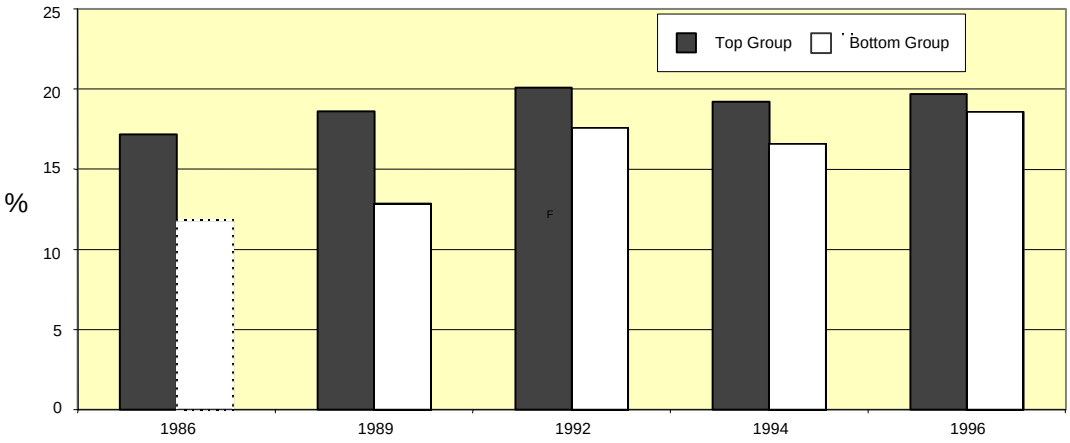
Table 4: Results of the second estimation

	Sample (31) 1986 - 1996	**Sample (31) 1986 - 1990**	**Sample (31) 1991 – 1996**
Capital:	0,52279 (16,48)	0,57288 (15,72)	0,44018 (9,737)
Labor	0,23647 (7,769)	0,24619 (7,333)	0,15659 (3,307)
R&D	0,21232 (12,42)	0,15386 (7,508)	0,35309 (14,36)
RBM	0,02842 (3,516)	0,02707 (2,959)	0,05014 (4,15)
Const.:	3,6996 (12,33)	3,6424 (11,12)	3,5943 (8,333)
R-Square: Durbin-Watson: (.....) T-Ratio	0,982 1,7815	0,9880 1,6536	0,9845 1,7175

In the bottom group the percentage is increasing remarkably in the second period. This might indicate that the firms of the bottom group do not only increase their R&D budget but at the same time try to stress the influence of technical know-how in the board.

Figure 4: Board members with research background in percent of the total board members – the two groups compared

Source: Kaisha-Database, own calculation



Summarizing the main results we can point out that:

(1) For the whole sample the emphasis on R&D increased remarkably in the second period,
(2) R&D is much more significant for the top group than for the bottom group which relies more upon capital,
(3) the estimated value for technical knowledge for the whole sample has doubled in the second period.

Anyway, high R&D budgets are no guarantee for success. It seems to be a necessity but by no means a sufficient explanation for long-term success.

3. Does efficient organization matter?

So far we have analyzed the different performance of the two groups focusing on the operating-profit-on-sales ratio and the emphasis on R&D activities. The gap between the two groups has been confirmed by the results of the estimated production functions. In a further step we will have a look at the structural characteristics of the two groups in order to find explanations for the different performance. The results are striking (see Table 5). A multi-layered organizational structure of the R&D-activities dominates in the first group.[26] A multi-layered organizational structure implies that a corporation has a central research laboratory and/or an independent research institute as well as research labs within the operating areas. All electronic giants in the sample show a multi-layered structure of research labs. With a functional structure on the other hand a firm is concentrating its R&D-activities in a single division or research institute. The functional structure type is represented more frequently in the second group. Which functional type is more efficient? A lot of research has already been conducted to find out what organizational structure characterizes an innovative firm.[27] No final solution has been found yet. Nevertheless the smooth interface management between the R&D department and the production department as well as the marketing department seems to be of special importance. Close personal links between these departments support the speed and success of innovation.[28] Our analysis (Table 5) shows quite clearly that the multi-layered form with R&D institutes abroad is more efficient. It is a dominant device for information gathering (labs abroad and in each division) and information processing (central R&D planning division).

An R&D-structure consisting of a central research laboratory involved in basic research activities besides divisional laboratories which concentrate on the commercialization of

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[26] It is not possible to understand the R&D structure precisely by analyzing the organizational structure published in the annual reports. Nevertheless it indicates the main tendency.

[27] See Lederer (1990) for an overview.

[28] See Albach (1993), p. 198-206.

prototypes in cooperation with factories, looks like offering an excellent basis for keeping up with new technology developments on the one hand and being quick enough to commercialize new ideas on the other hand. Nevertheless transaction costs are to be considered in a decentralized organization. It implies always the danger of being too complex which makes it hard to control. There is danger of misdirected information or misunderstanding. But Japanese firms are said to be very efficient in coordinating different divisions. Westney (1994) points out that the relatively recent evolution of R&D-structures in big Japanese corporations supported the close links between the central and the divisional laboratories and between the divisional laboratories and the factories. These close links guarantee an efficient information flow and constitute the roots for strong „structural isomorphism between R&D and manufacturing“[29] An element of special importance for the functioning of this networking approach in R&D is the high mobility of engineers between the different research levels. This human interchange supports a quick and smooth technology transfer.[30] Nevertheless changing the R&D structure in order to strengthen the efficiency seems to be an important issue of Japanese corporations as well. Only recently at least eight huge electronic corporations of this sample modified their R&D-structure in order to strengthen the efficiency of their R&D-activities.[31]

Future discussions about a reorganization of the R&D structure might concentrate on the importance of the expensive central research laboratories. Although it is not likely in the next future that the research done in the central research laboratories can be replaced by cooperation with universities as usual in the U.S. Joint industrial research cooperation is a possibility to cut costs of basic research projects. These are increasing among Japanese electronic corporations as well as the strategic alliances with small - mostly U.S. based - American set-ups in the high-technology sector.

A separate R&D-strategy division within the corporate headquarters seems to be no matter of size. In the first period only 4 firms within the first group showed a division for R&D strategy planing in their organizational structure, two of them being of rather small size. In the second period three corporations of both groups established a division especially responsible for R&D-strategy (see. Table 5). The higher number of R&D planning divisions (most of them established at the end of the 80s, beginning of the 90s) in the first group supports the results of a study of strategic R&D management systems in Japanese corporations by Sawada et al. They noticed a tendency that companies with a separate division for R&D strategy planning are more progressive in their basic attitudes towards the R&D environment and R&D management and that they display generally a better R&D performance than companies without a separate division.

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29 Westney (1994), p. 166.

30 For further details see Ito (1994), p. 224-231.

31 See Enomoto 1996, p. 34 for details.

Table 5: Structural differences of the two groups
Source: Kaisha-Database, own calculation

	Top Group		Bottom Group	
Mean value	**1986 - 1990**	**1991 - 1996**	**1986 - 1990**	**1991 - 1996**
R&D structure: functional	5	5	10	10
R&D structure: multi-layered	10	10	6	6
Number of companies with research institutes abroad		8		4
Existence of central R&D planning division	4	7	0	3

They summarize that R&D strategy planning „will become the foundation upon which companies can improve their R&D environment“.[32]

The internationalization of R&D activities has been strengthened by Japanese high technology corporations at the end of the 1980s. This is a general trend within the Japanese manufacturing industry. In 1992 approximately one-fifth of Japanese manufacturing facilities in Europe were associated with a research unit, three years earlier the proportion had been one-tenth.[33] A survey carried through by Pearce/Singh (1992) shows that autonomous overseas laboratories are of continuous interest for Japanese firms. Additionally they put a special emphasis on a globally integrated R&D network.[34] Strategic research and development seem to no longer have a geographical border. Kümmerle (1997) points out that the sources of potential knowledge around the globe are increasing and that corporations have to absorb new knowledge into their own organizations wherever it arises. Furthermore in a time of rapid product life cycles they have to be involved in the trends of the local markets in order to achieve the speed in commercializing new ideas required to remain competitive.[35]

Within the first group there is proof of eight firms to have research laboratories abroad whereas in the second group the number is half as much. Mainly the huge corporation engaged in the IT and communication business seem to pursue this strategy. None of the electric machinery producers published corresponding information.

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32 See Sawada et al. (1993), p. 66

33 See Papanastassiou/Pearce (1994): 158.

34 Four possible attitutes to future R&D strategy were presented to firms in Japan, USA and Europe. See Singh/Pearce (1992).

35 See Kümmerle (1997), p. 61.

Summarizing the main differences of the two groups we find that the top group seems to have a more efficient R&D structure due to:

* a higher number of researcher,
* a higher level of R&D budgets and
* an organizational structure which promotes research activities on different levels,

as well as a better flow of information indicated

* by a global approach to R&D activities,
* the existence of strategic R&D planning divisions
* and a high representation of manager with R&D background in the board.

Further research will focus on the global research activities and their rank in the R&D strategy of the Japanese firms. Moreover the changes of the human resource management will be analyzed in the context of the globalization of R&D activities and the changing patterns of the Japanese labor market in order to find out what impact these activities and changes have on information gathering and information dissemination in the corporations.

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APPENDIX

Table: A1: The R&D to sales ratio in different industries compared

(Source: Kagaku gijutsu hakusho 1997, p. 458)

(in %)	1986	1989	1992	1995
Manufacturing Industry	**3.03**	**3.29**	**3.52**	**3.43**
Chemical	**3.56**	**4.09**	**4.19**	**4.24**
Pharmaceutical	**6.89**	**7.5**	**8.7**	**8.03**
Machinery	**2.77**	**2.83**	**3.1**	**3.26**
Electrical Machinery	**5.5**	**5.89**	**6.17**	**5.82**
Electrical appliances	**5.23**	**2.47**	**5.66**	**5.83**
Information Technology (IT)	**5.63**	**6.1**	**6.42**	**5.81**

Table: A2: Ranking of the sample according to R&D to sales ratio (in percent) and sales and R&D figures (in mio. Yen) for 1996

Source: Kaisha Database, Japan Company Handbook, own calculation

1996	1992	1989	1986	NAME	Sales	R&D	Ratio
					1996	1996	1996
1	3	3	3	Sony Corporation	1,930,998	257,326	13.33
2	2	1	4	Matsushita Communication Ind, Co,, Ltd,	499,441	61,300	12.27
3	1	2	2	Fujitsu Ltd,	2,602,216	295,200	11.34
4	5	6	6	Hitachi Ltd.	4,126,419	379,576	9.20
5	10	7	7	Matsushita Electric Industrial Co.. Ltd.	4,441,714	399,700	9.00
6	11	11	11	Sharp Corporation	1,281,752	115,330	9.00
7	4	4	1	NEC Corporation	3,448,793	310,000	8.99
8	7	5	5	Japan Radio Co.. Ltd.	155,172	13,420	8.65
9	21	24	18	Hitachi Koki Co..Ltd.	113,307	9,498	8.38
10	8	10	10	Omron Corporation	401,986	32,700	8.13
11	9	9	8	Toshiba Ltd.	3,713,022	294,600	7.93
12	16	18	28	Sanyo Electric	1,075,139	85,077	7.91
13	20	20	19	Pioneer Electronic Corporation	351,952	27,600	7.84
14	17	12	14	Kyushu Matsushita Electric	286,765	21,295	7.43
15	14	19	22	Victor Company of Japan. Ltd.	562,589	38,500	6.84
16	6	8	15	Kokusai Electric Co.. Ltd.	163,377	11,040	6.76
17	18	21	20	Osaki Electric Co.. Ltd.	22,837	1,531	6.70
18	15	17	16	Tokyo Electric Co.. Ltd. (TEC)	200,067	13,116	6.56
19	13	13	9	Oki Electric Industry Company. Ltd.	556,345	36,000	6.47
20	12	14	12	Mitsubishi Electric Corporation	2,751,770	175,000	6.36
21	23	15	26	Aiwa Co.. Ltd.	256,044	15,000	5.86
22	19	23	17	Clarion Company	122,315	7,077	5.79
23	24	16	13	Fuji Electric	560,138	31,095	5.55
24	25	25	21	Meidensha Electric Mfg.Co.. Ltd.	175,280	9,474	5.41
25	22	26	23	Yaskawa Electric Corporation	139,673	7,294	5.22
26	30	29	27	Matsushita Refrigeration Company	166,735	7,400	4.44
27	29	31	31	Kenwood Corporation	211,477	9,300	4.40
28	26	27	29	Sanken Electric Company. Ltd.	114,544	4,887	4.27
29	28	28	24	Teac Corporation	102,138	3,800	3.72
30	27	22	25	Fujitsu General Ltd.	167,117	6,157	3.68
31	31	30	30	Makita Corporation	103,317	3,094	2.99