

# Optimal Diversity Management for R&D by Medical Device Manufacturers in Japan

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## Abstract

In the medical device industry in Japan, it is believed that Japanese therapeutic devices are vulnerable to tough international competition, while diagnostic devices are internationally quite competitive. In recent years, however, some Japanese companies have achieved remarkable breakthroughs in the therapeutic device field. Terumo Corporation, a Japanese medical device manufacturer, is a case in point. This paper examines Terumo's technological and cultural diversity by comparison with its competitors. It suggests that there may be an optimal diversity for R&D related to medical devices.

## Introduction

In the "Industrial Society", enterprises mainly managed labor, materials and finances. In the 21st century, the century of the "Knowledge Society", they are required to recognize the importance of knowledge as a fourth essential resource, since new knowledge generated by innovation has become the key to business success.

Analysis of the creation and transfer of knowledge has become an essential element in developing competitive strategy and theory of innovation. The growing centrality of this element reflects the sophistication of industrial structures, the increasing importance of knowledge work, geographical dispersion of

scientific technology on a global scale, R&D, increased risk, increasing importance of adaptation to global markets, as well as the tendency to speeding up of product development. As discussed in "Open Innovation" (Chesbrough 2003, 2006) incorporation of external knowledge sources is becoming ever more important.

In a changing competitive environment, business enterprises are urged to develop more differentiated products that enable them to gain an advantage in global competition. In particular, the creation of new concepts and technological knowledge became more essential than ever before.

For medical devices developed with cutting edge technology, it is crucial to create knowledge. The technology level in Japan of electronics, semiconductors and materials is the highest in the world. Since these are core technologies for medical devices, Japan's edge in these areas should be reflected in medical device technology. However, regarding the medical device products in Japan, the export-import balance exhibits an excess of US\$5.7 billion in imports and the development of medical devices in Japan lags far behind that in the US and Europe. In particular, devices used for medical treatment that pose a risk to human lives are rarely developed in Japan. This is the situation in which the Terumo Corporation (hereinafter, Terumo), one of the top medical device enterprises in Japan, has taken on the challenge of developing cutting

edge therapeutic devices, and has steadily improved its sales.

This study discusses Terumo's technological development of cutting edge products in the therapeutic device field, focusing on the importance of diversity management in R&D.

For purposes of this study financial reports and the number of patent applications filed by Terumo and one of its competitors in the same field are compared. Patent applications result from R&D, and the knowledge generated by R&D appears as inventions in patent applications.

### Methodology

The two companies compared are Terumo and the Nipro Corporation (hereinafter, Nipro). Terumo has established the top sales in the medical device market in Japan. Nipro is similar to Terumo in the turnover (Fig.1) and is also listed in the first section of the Tokyo Stock Exchange in the precision equipment sector. The number of employees (Fig.2) in Terumo was about the same as Nipro in 2000, but grew to 1.4 times larger in 2009. As of 2009, Terumo's ordinary income (Fig.3) is substantially higher than Nipro.

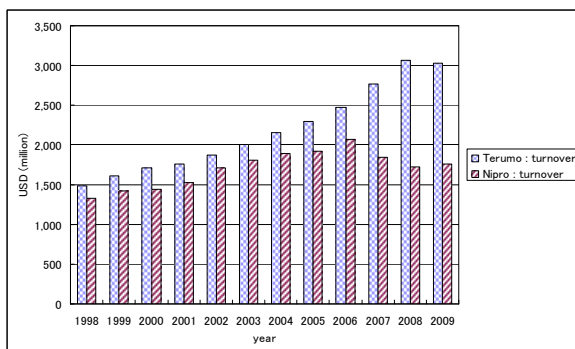


Figure 1. The trend of Turnover

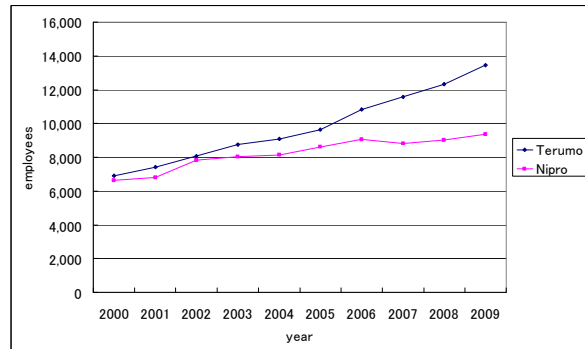


Figure 2. Number of Employees.

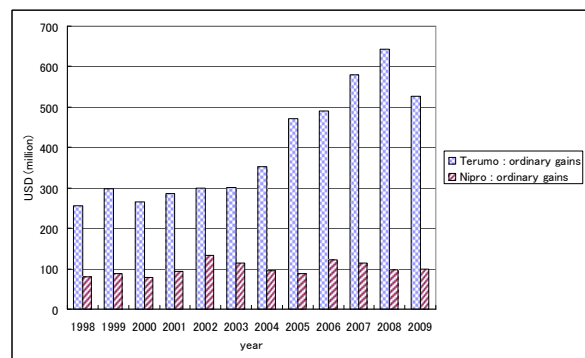
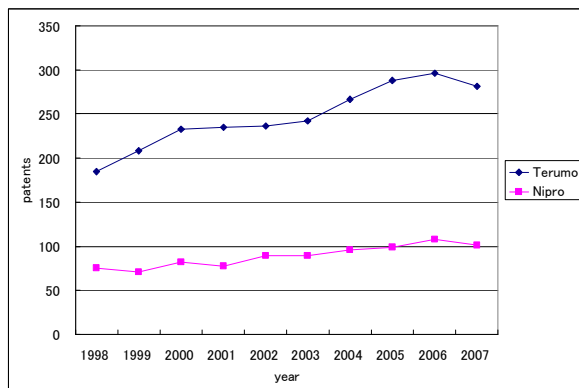


Figure 3. The trend of Ordinary Income.

**Financial Data.** R&D expenditure and the facility investment for 12 years (from 1998 to 2009) of Terumo and Nipro were compared, using the ratio (A)R&D expenditure/(B)facility investment as an indicator .

**Patent Application Data.** Patent application data filed with the Japan Patent Office from January 1, 1996 to December 31, 2008 were also compared. The number of applications filed by Terumo was 1,999 and the number of those filed by Nipro was 1,013 during that period. To smooth change over years and make it easier to spot trends, a three-year moving average was calculated using raw data from 1996 to 2008, and the result plotted for the 11 years from 1998 to 2008. (Fig. 4)



**Figure 4. Number of Patent Applications: Moving Average for 3 years.**

Keyword descriptions of inventions were extracted for each patent specification, using the search engine for patent publications provided by the Patent Result Co. in Japan.

**Analysis of Applicants.** Patent applications from 1996 to 2008 were divided into 5 groups by inventors or applicants: application by the inventors the applicant company, application including the inventors of other companies than the applicant, joint application with other companies, joint application with universities, hospitals or laboratory (research organizations), and joint application with other individuals. Joint applications are treated as the results of co-invention or joint R&D.

**Multiple Technology Patents.** In order to analyze technological diversity using existing patent data, applications were divided into multiple-technology and single-technology patents. The IPC (International Patent Classification) was used to specify the technologies included in patent applications related to catheter technologies. We conducted the text search for the patent laid-open publications at the IPDL (Industrial Property Digital Library) provided by the National Center for Industrial Property Information and Training.

First, we calculated the number of IPC(s) included in each patent application and grouped applications as 1-technology, 2-technology, 3-technology, 4-technology patents or more according to the number of IPC(s). Then, we counted the numbers of 1-, 2-, 3- technology patents and 4- or more-technology patents year by year. We define 1-technology patents as single technology patents and 2-, 3-, 4- or more technology patents as multiple-technology patents. We compared the number of single technology patents with the number of multiple technology patents and used these comparisons to index the number of technologies involved in inventions. Here, we also used the moving three-year averages prior to 1996 and the original values from 1996 onward.

## Results and Discussions

**R&D Efficiency.** Although R&D expenditure (Fig.5) has been increased by both Terumo and Nipro, the difference between them has grown from 2.8 to 1 in 1998 to 3.2 to 1 in 2009. With respect to the facility investment (Fig.6) that is the Plant & Equipment Investment Cost, Terumo's investment amount was 3.4 times larger than that of Nipro in 1998, but Nipro's became larger in and after 2001 except 2005 and 2006. In 2009, Nipro's was larger than Terumo's by 28%. Terumo's investment was larger 2006 when they purchased a US company and refurbished factories in the Philippines and Japan. (From Terumo's annual financial statement report in 2006)

The ratio (A) R&D expenditure / (B) facility investment as an indicator of R&D efficiency is shown in Fig.7. Changes in this figure show that Nipro's ratio (A)/(B) decreased from 1998 to 2003. The average of the ratio (A)/(B) during 1998 to 2009 of Nipro is 0.2, while that of Terumo is 0.9. (Kodama 1991) reported, using this same ratio as an indicator, that R&D expenditure by Japanese manufacturers

exceeded facility investment in 1986 for the first time. (Kodama 1991) also reported that manufacturers who learn about technologies from early adopters and invest in facilities using these technologies achieve sales and profits. Since they enjoy a partial free ride when it comes to the technologies their facility investments tend to exceed R&D expenditures. This analysis may apply to Nipro.

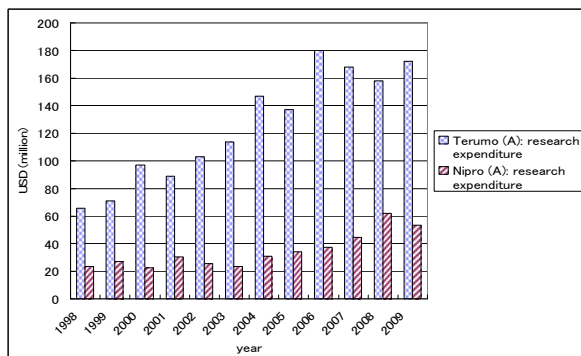


Figure 5. R&D Expenditure.

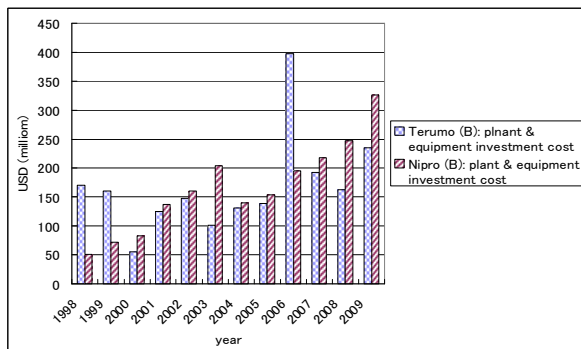


Figure 6. Facility Investment.

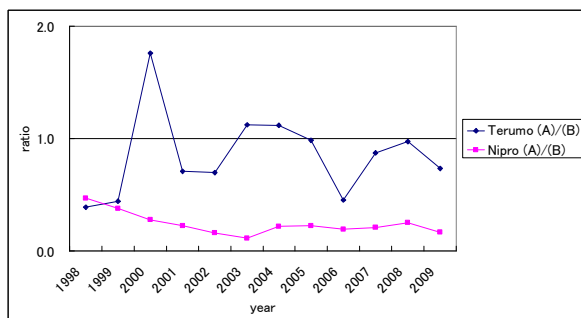


Figure 7. R&D Efficiency.

**Breakdown of the Patent Applications.** Figures 8 and Figure 9 show the number of

patent applications filed by Terumo and Nipro from 1996 to 2008 grouped by specific technologies.

We can see that Terumo filed a larger number of patent applications for inventions of advanced controlled medical devices such as therapeutic devices (catheters, guidewires) than Nipro. Nipro filed a larger number of patent applications for low risk devices (containers, tubes) and dialyzers, which Terumo does not produce.

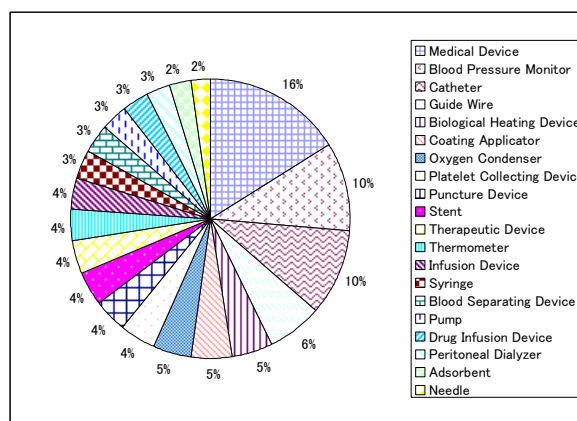


Figure 8. Terumo: Breakdown of the technologies.

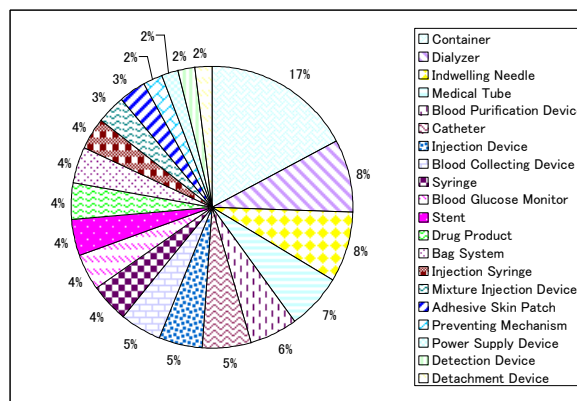


Figure 9. Nipro: Breakdown of the technologies.

**Joint Research/Joint Invention.** What we can see in both companies is that, although 90% of applications were submitted by internal inventors only in 1998, the number of joint applications involving external inventors had increased by 2008, to 80% for Terumo (Fig.10),

and 70% for Nipro (Fig.11). In Terumo's case, joint applications with other private firms increase, while in Nipro's case, joint applications with universities, hospitals and research institutes increase. In other words Terumo tends to incorporate new knowledge from other companies, that is, the business world, while Nipro turns, instead, to universities, hospitals and research institutes, that is, the academic world.

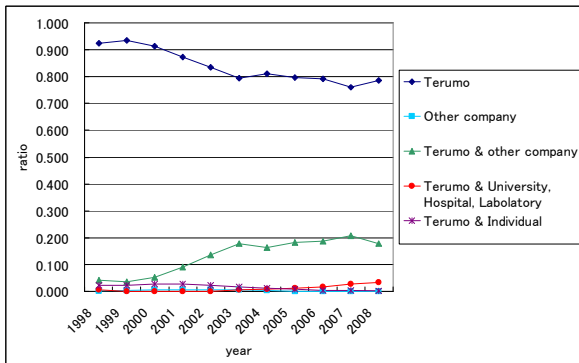


Figure 10. Terumo: The result of Applicant analysis.

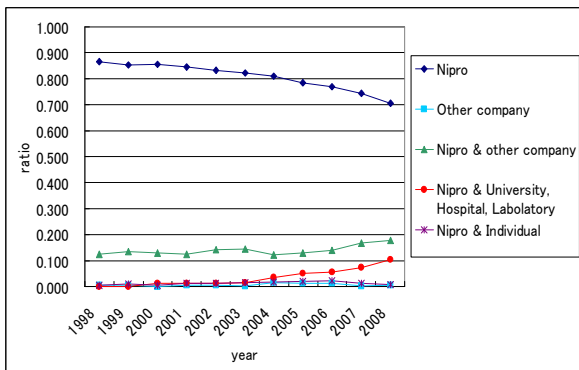


Figure 11. Nipro: The result of Applicant analysis.

**Technological Diversity.** Figure 12 shows the trend in the ratio of multiple-technology patents (patents designated in more than one technology field) in total patent applications filed by Terumo and Nipro from 1998 to 2008. Here we can see that more than half of patent applications submitted by Terumo and Nipro were multiple-technology patents during the three

years from 2000 to 2002. In 2008, approx. 45% were multiple-technology patents at both companies.

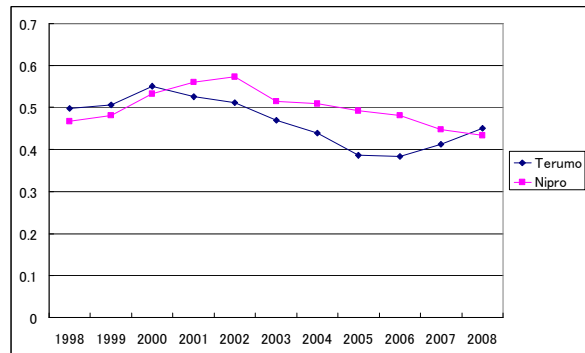


Figure 12. The trend in the ratio of Multiple-technology Patents (Terumo and Nipro).

Next, we broke down the multiple-technology patents into 2, 3, and 4 or more technology patents, and observed how their numbers changed over the years (Fig.13) (Fig.14). We can see that the largest proportion (30%) of applications filed by both Terumo and Nipro were for 2-technology patents, followed by 3-technology patents (10%).

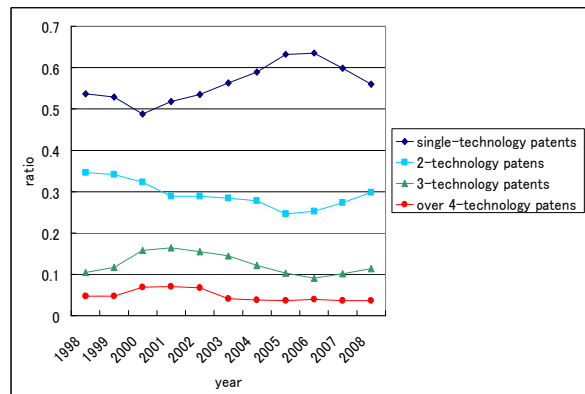
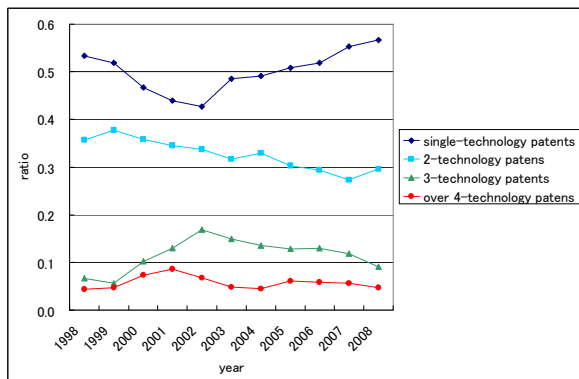
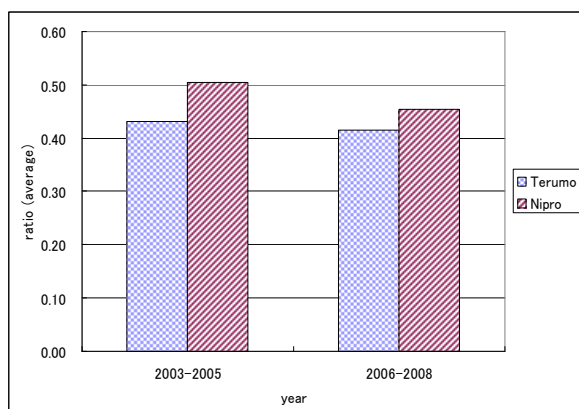


Figure 13. Terumo: Multiple-technology Patents.



**Figure 14. Nipro: Multiple-technology Patents.**

Next we examined multiple-technology patents for 6 years from 2003 to 2008. Figure 15 compares the average share of multiple-technology applications for the first and second three-year periods respectively. It shows that Terumo's average ratios were around 40% in both periods, while Nipro's average ratio decreased by 5%, from 50% (2003-2005) to 45% (2006-2008). At Nipro the share of multiple-technology patents decreased, and that of single-technology patents increased during the second 3-year period.



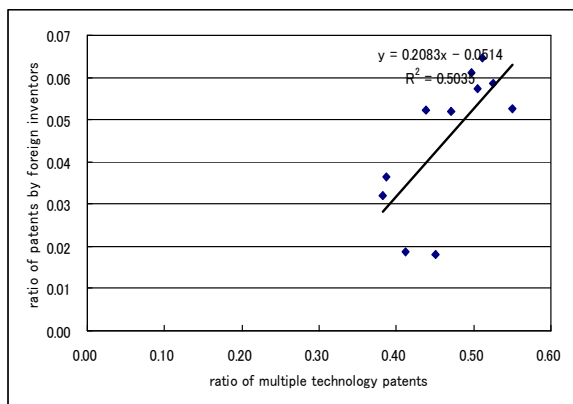
**Figure 15. Terumo vs Nipro: The ratio of Multiple-technology Patents (Ave.).**

**Correlations between Diversity of Inventors and Multiple-technology Patent.**  
In this phase of the research, we treated patents

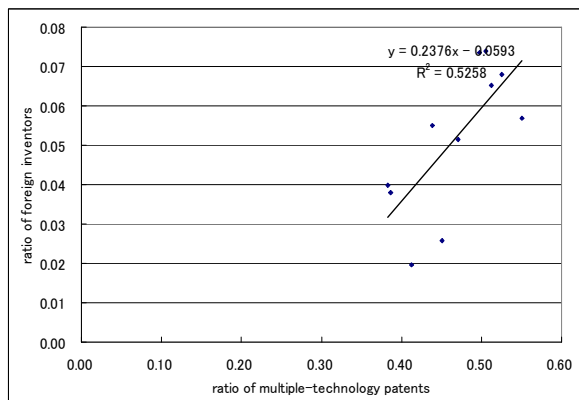
as the outcomes of R&D activities, and attempted to measure cultural and technological diversity at the two companies using classifications of the types of institutes to which the inventors (researchers) belonged, their gender, nationality, and the technology fields involved. We focused, in particular on the correlation of multiple technology patents with diversity in gender and nationality. Figure 16 and Figure 20 show the correlation between the ratio of multiple-technology patents in total patent applications in a year (hereinafter, “the ratio of multiple-technology patents” and the ratio of patent applications by inventors including one or more foreigners in total patent applications in a year (hereinafter, “the ratio of patents by foreign inventors”) for Terumo and Nipro. Both companies show a positive correlation, 0.71 and 0.75, respectively. (Table 2) Figure 17 and Figure 21 show the correlation between the ratio of multiple-technology patents and the ratio of foreign inventors in total inventors of patent applications in a year (hereinafter, “the ratio of foreign inventors”) for both Terumo and Nipro. Here, again, we find strong positive correlations, 0.73 and 0.80. (Table 2) Meanwhile, Figure 18 and Figure 22 show the correlation between the ratio of multiple-technology patents and the ratio of patent applications by inventors including one or more female in total patent applications in a year (hereinafter, “the ratio of patents by female inventors”) for Terumo and Nipro. For Terumo, the correlation coefficient was -0.33 showing a little negative correlation, and for Nipro, the correlation coefficient was -0.71 showing a strong negative correlation. Figure 19 and Figure 23 show the correlation between “the ratio of multiple-technology patents” and the ratio of female inventors in total inventors of patent applications in a year (hereinafter, “the ratio of female inventors”) for Terumo and Nipro. For Terumo, the correlation coefficient was -0.49 showing a small negative correlation, and for Nipro, the coefficient was -0.70

showing a strong negative correlation.

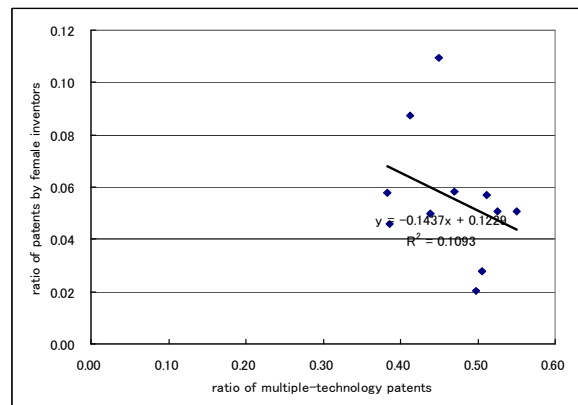
Those results above showed that there is a strong correlation between the ratio of multiple-technology patents and the ratio of patents by foreign inventors, and also the ratio of foreign inventors both at Terumo and Nipro. Turning, however, to the correlation between the ratio of multiple-technology patents and the ratio of patents by female inventors and the ratio of female inventors, we find a strong negative correlation at Nipro and only a small negative correlation at Terumo.



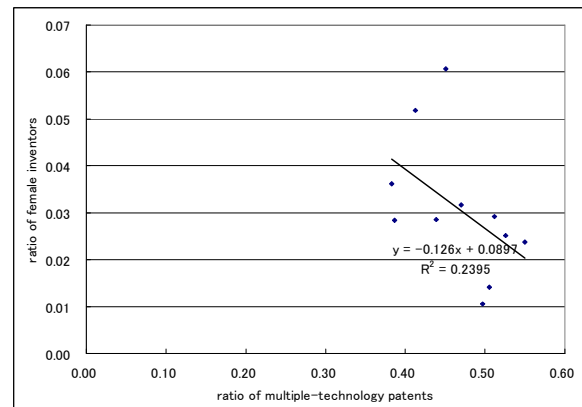
**Figure 16. Terumo: Patents by Foreign Inventors vs Multiple-technology Patents**



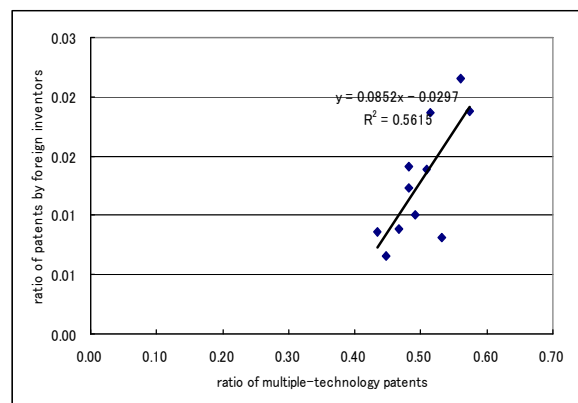
**Figure 17. Terumo: Foreign Inventors vs Multiple-technology Patents**



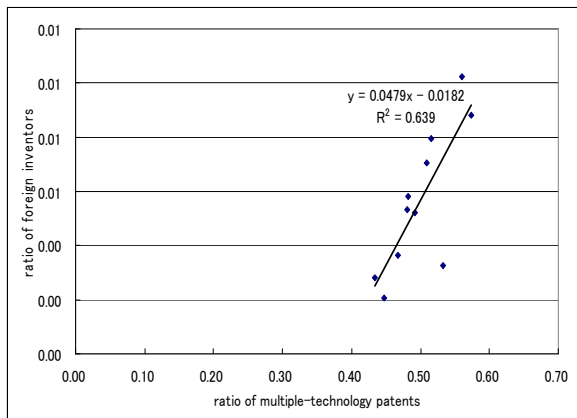
**Figure 18. Terumo: Patents by Female Inventors vs Multiple-technology Patents**



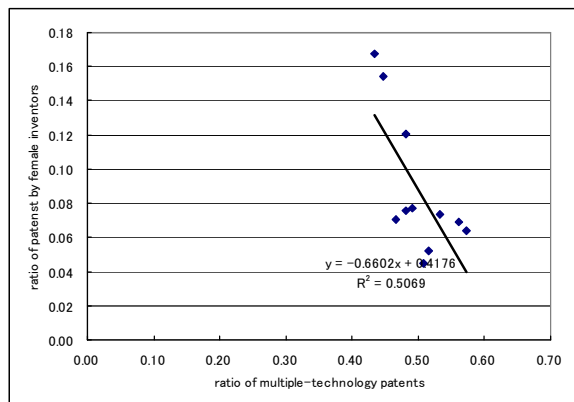
**Figure 19. Terumo: Female Inventors vs Multiple-technology Patents**



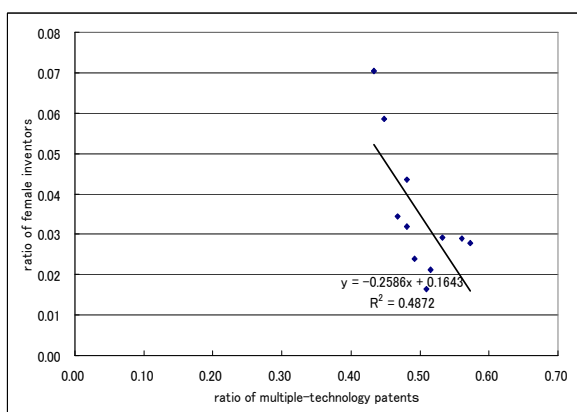
**Figure 20. Nipro: Patents by Foreign Inventors vs Multiple-technology Patents**



**Figure 21. Nipro: Foreign Inventors vs Multiple-technology Patents**



**Figure 22. Nipro: Patent by Female Inventors vs Multiple-technology Patents**



**Figure 23. Nipro: Female Inventors vs Multiple-technology Patents**

**Table 2: Correlations between the ratio of Multiple-technology Patents and the ratio of Patents/Inventors (Terumo vs Nipro)**

	the ratio of multiple-technology patents	
	Terumo	Nipro
the ratio of patents by foreign inventors	0.71	0.75
the ratio of foreign inventors	0.73	0.80
the ratio of patents by female inventors	-0.33	-0.71
the ratio of female inventors	-0.49	-0.70

## Discussion

Terumo has been showing balanced R&D efficiency since 1999 to date, while Nipro has shown less efficiency because of higher facility investments. Nipro appears to be a follow-the-leader manufacturer.

Analysis of the titles of patent applications from 1996 to 2008 reveals that Terumo filed many patent applications for advanced devices (catheters, etc.), while Nipro filed patents for more ordinary devices (containers, etc.)

This analysis also reveals that Terumo is more likely than Nipro to undertake joint research with other private companies, while Nipro relies more on joint research with academic institutions.

In comparisons of changes in the ratio of multiple-technology patents between the periods 2003-2005 and 2006-2008, Terumo showed little change, but Nipro showed a substantial decrease. This suggests that, at Nipro, R&D involving multiple technologies may have decreased, reducing its ability to create innovative new technologies.

Both Terumo and Nipro show a strong correlation between the multiple-technology patents and the patent applications by inventors including one or more foreign inventors. Multiple-technology patents involve more than one technology combined in innovative ways.

New technologies are generally created by a new combination of technologies and, the more combinations are involved, the more new technologies will be created. These results suggest, therefore, that cultural diversity introduced by joint products involving foreign inventors can stimulate the development of new technology and innovative product concepts.

### Concluding Remarks

The medical device industry is one of the industries where knowledge creation is essential for business success. The creation and transfer of knowledge are essential for development of competitive new products. Strengthening cultural and technical diversity can lead to greater innovation. This study examined diversity management by Terumo and Nipro. Using patent applications, it suggests the possibility that the combination of involving foreign inventors and incorporating multiple technologies will spur new product development.

This study is, of course, only a preliminary comparison of two companies and also employed three-year moving averages to reduce data scattering. Both data on more companies and more sophisticated statistical analysis are needed to confirm or refine its findings. Follow-up interviews at both Terumo and Nipro are also needed to enrich the findings.

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### Biography

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Tomoko Saiki is currently a professor in the Department of Technology Management, Tokyo Institute of Technology (TIT). She is graduated from Osaka University with a Bachelor's degree in Pharmacology in 1970 and a Master's Degree in Pharmacology in 1972. She joined the Japan Patent Office (JPO) in 1972 and is a former Director of Medical and Science Division. She joined FANCL Corporation in 2001 and is a former General Manager of Intellectual Property Management Department.