Chapter 6
Organizational Design and Human Resource Management of R&D Activities

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Abstract This chapter elucidates the relationship between innovation outcome and organizational design of research and development (R&D) activities including human resource management (HRM) within a firm. This chapter first reviews the related literature on the interaction between organizational and human resource management (OHRM) and innovation. The chapter then focuses on three types of management practices: cooperation and coordination across firm business units or divisions overall, HRM of R&D personnel, and restructuring the organization of R&D. The chapter provides a detailed overview of the characteristics of Japanese firms' patenting activities by combining two datasets, the Japanese National Innovation Survey (J-NIS) 2009 and the Institute of Intellectual Property (IIP) Database. The chapter then focuses on OHRM practices and patent applications as a proxy for innovation outcome.

Keywords Human resource management • Innovation • Organization • Patent • R&D

6.1 Introduction

What affects and what determines successful innovation? This question has been a focus for business managers, entrepreneurs, and policy makers. Many firms have implemented organizational and human resource management (OHRM) in research and development (R&D) centers or divisions to innovate new products. As a recent example in Japan, Shiseido, a global cosmetic company, announced a plan to

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reform R&D organization and establish one of the world's largest cosmetic research facilities in the city of Yokohama.[1] Shiseido uses an open lab environment where innovation is conducted in a vibrant space, buzzing with activity, which enables customers, marketers, and researchers to mingle daily, strengthening basic and generic research in new fields.

In academic articles, Teece (1996), for instance, argued that an important determinant of innovation is firm organization. Researchers should understand the importance of market structure, the business environment, and the formal and informal structures of firm organization, where formal structures include factors such as scale, scope, integration, and hierarchy while informal structures are composed of a firm's organizational culture, including its norms, values, and the shared identity within the firm. Quantitative evidence indicates that organizational factors are determinants central to innovation inputs and outputs. For example, estimating patent production functions, Pakes and Griliches (1984) found that the magnitude of the coefficient on R&D investment fell drastically when firm-specific effects were controlled. Meanwhile, Scott (1984) found that firm fixed effects explained approximately 50% of the variance in R&D intensity. These results imply that there are unobserved firm-specific factors that greatly affect innovation activities. While neither of these two studies nor any subsequent research explores the key determinants of such firm-specific effects, one possible explanation of the results is that firm-specific organizational practices play a role in determining firms' innovation outputs and inputs.

The literature has increasingly focused on various features of organizations, including (1) the design of incentive systems, (2) the firms' ability to manage spillovers of knowledge, and (3) the firms' choice of organizational structure. OHRM is the most important form of nontechnological innovation and the most difficult to grasp both on a conceptual and on an empirical level. Azoulay and Lerner (2013) noted that most knowledge does not stem from the mining of traditional datasets such as large-sample survey census-type datasets. There are data constraints and methodological problems related to the availability of appropriate indicators to measure OHRM on firm-level innovation. In addition, empirical examinations on organizational R&D management are relatively scarce. Instead, the literature investigates, for example, the relationship between firm productivity and firm-wide management practices such as the role of teams, payment schemes, and training for workers overall, without specifically focusing on management practices for researchers and/or research units.

This chapter examines in detail the characteristics of organizational management and innovation activities of Japanese firms. For the analysis, this chapter uses the firm-level data underlying the Japanese National Innovation Survey (J-NIS) conducted by the Ministry of Education, Culture, Sports, Science and Technology in 2009. The survey is the Japanese equivalent of the Community Innovation Survey

[1] For more details, see the Nikkei website, March 27, 2015: http://www.nikkei.com/ (accessed on September 20, 2016).

(CIS) conducted in the European Union. The J-NIS contains rich information on innovation inputs such as financial support from public sectors, cooperation for innovation, or information sources for innovations. The survey similarly includes information on innovation outputs such as realizing product/process innovations, effects of innovation, or sales of new-to-the-firm innovations except for the information on patenting activities.

This chapter is novel because I also use firm-level patent application data from the Institute of Intellectual Property (IIP) Database for the reference years from the J-NIS 2009. This chapter reviews the characteristics of Japanese innovating firms with patent applications using the number of co-applicants or the types of co-applicants and their innovation inputs and outputs. The chapter then investigates the relationship between firm-level information on OHRM and patent application. It has been frequently suggested that OHRM should be reformed in response to changes in the functions of the central research institute, incentives to innovate, and the attribution of invention to researchers. The results of this chapter could be useful to show the effectiveness of OHRM on innovation by focusing on eight management practices.

The remainder of this chapter is organized as follows. The following section provides a survey of the related literature and highlights the importance of organizational factors as determinants of innovation outcome. Section 6.3 describes the dataset used in this chapter and discusses various characteristics of innovation activities of Japanese firms. Section 6.4 concludes with some remarks.

6.2 Related Literature

This section briefly explains the importance of organization factors as determinants of successful innovation based on the literature by Teece (1996). The section then reviews the findings of previous empirical studies and summarizes the issues on the role of OHRM for innovation activities.

Teece (1996) focused on the importance of strength of innovation activities to the formal and informal structures of a firm. Specifically, innovation tends to be characterized by uncertainty, path dependency, and technological interrelatedness. Innovation tends to be cumulative in nature and to exhibit irreversibility; knowledge is often tacit, and innovations can be difficult to appropriate. Given these underlying properties of technological innovation, Teece (1996) identified the organizational requirements for innovation success: (1) joint research projects or alliances with other firms to obtain better access to capital, (2) cooperation and coordination across business units or divisions to mitigate various types of uncertainties, (3) horizontal and/or vertical integration of organizational subunits such as R&D, manufacturing, and marketing to attain economies of scope and successfully commercialize innovations, and (4) human resource management (HRM) practices to develop corporate norms and instill them in employees. Based on Teece's (1996) discussion, this chapter – reflecting data availability – focuses on the following three broad types of management practices: (1) cooperation and coordination across business units or divisions of the firm, (2) HRM of R&D personnel, and (3) restructuring of organizational R&D. The remainder of this section reviews the findings of previous empirical studies on these types of management practices.

First, cooperation and coordination across business units or divisions are expected to increase knowledge spillovers within a firm and to improve firm performance. A substantial number of studies have correlated various aspects of firms' performance with various management practices. Bloom and Van Reenen (2007), for example, constructed original data with a sample of 732 medium-sized manufacturing firms in the USA, the UK, France, and Germany by collecting accurate responses and obtaining interviews with managers. Bloom and Van Reenen (2007, 2011) mainly focused on the effects of HRM on productivity as the key outcome and, thus, elaborately surveyed the related literature. The authors expected any changes in HRM to produce a positive outcome, on average, because firms improve their productivity through optimization, and the authors also expected the introduction of incentive pay to affect the type of workers who wanted to join and leave firms. Their results indicated that the management scores calculated in their research were strongly associated with measures of firm performance such as productivity, Tobin's q, and sales growth.

Bloom and Van Reenen (2007) calculated management scores as the simple average of scores across 18 questions related to both OHRM issues. The authors' measures of management practices thus include both OHRM practices and do not separate the effects of each type of management practice. Although this approach makes sense in certain respects – because some management practices are mutually complimentary, and it is not straightforward to attach weights to individual practices – an average score makes identifying the management practices most important for the determinants of firm performance difficult. Focusing on organizational management practices, Evangelista and Vezzani (2010), using a large micro dataset of European CIS from 2002 to 2004, showed that organizational innovations have a positive and significant impact on sales growth for firms in many of the European manufacturing industries. Evangelista and Vezzani (2010) attempted to capture nontechnological content of innovations and to distinguish organizational innovations from marketing innovation based on the questions.[2] However, the authors did not separate the effects of each type of management practice.

Second, a subject that has received considerably more attention is the role of incentive systems such as pay for performance. Incentives include remuneration

[2]CIS asked whether firms had (1) implemented new or significantly improved management systems, (2) made a major change to the organization of work within the enterprise, such as changes in the management structure or integrating different departments or activities, (3) introduced new or significant changes in relations with other firms such as alliances, partnerships, outsourcing, and subcontracting, (4) made significant changes to the design or packaging of a good or service, and (5) introduced new or significantly changed sales methods or distributions channels such as Internet sales, franchising, direct sales, or distribution licenses.

systems such as individuals/group incentive/contingent pay, appraisal, promotion, and career advancement programs. Managers design various reward programs mixed with extrinsic reward programs, such as incentive pay, and intrinsic reward programs, such as performance-based evaluation systems, to stimulate employee motivation. Theoretical and empirical research presents conflicting findings on the relationship between extrinsic rewards and innovation outcomes represented by new products and services, productivity, or profitability. Many studies indicate that extrinsic rewards are ineffective when employees are charged with tasks that require innovation and creativity.

Studies on pay for performance have thus produced mixed results. While some literature showed that compensation based on the pay-for-performance principle induces higher levels of effort and productivity (e.g., Lazear 2000; Shearer 2004), other studies highlighted the distortions associated with incentive pay schemes (e.g., Bloom and Van Reenen 2011). Meanwhile, using a large micro dataset on inventors, Nagaoka et al. (2014) examined the relationship between revenue-based payments for inventions and research outcomes proxied by the number of patent citations. The authors found that although incentive pay schemes tend to increase the number of patent citations (i.e., they result in higher quality inventions), the effects depend on the degree of inventors' intrinsic motivation for science. Intrinsic motivation is based on researchers' enthusiasm for exploration and implies that researchers work on a project because they find it personally rewarding. On the other hand, monetary incentives provide only extrinsic incentives, and Nagaoka et al. (2014) found that for inventors with greater intrinsic motivation, incentive pay schemes have smaller positive effects. Onishi (2013) found that although monetary compensation from incentive pay schemes leads to an increase in the number of patent citations, it does not contribute to an increase in the number of patents. The results are consistent with the findings of Stern (2004), who, using a dataset on job offers for postdoctoral biologists, observed a negative relationship between intrinsic and extrinsic incentives. These studies suggest that firms need to design incentive schemes that do not crowd out researchers' intrinsic motivation to innovate.

Studies that statistically examined the relationship between remuneration schemes and innovation include those by Lerner and Wulf (2007), Yanadori and Cui (2013), and Kanama and Nishikawa (2015). Lerner and Wulf (2007) analyzed the relationship between the compensation of senior executives and R&D outcomes and found that long-term incentives, such as stock options, are associated with heavily cited patents. In contrast, Yanadori and Cui (2013) focused on the compensation of R&D employees and found that pay dispersion among R&D employees in US high-tech firms is negatively associated with firm innovation proxied by the number of successful patent applications. The results suggest that large pay differentials among employees decrease employees' collaboration as well as preclude innovation. Kanama and Nishikawa (2015) examined the effects of extrinsic rewards for R&D employees on innovation outcomes using a sample of 942 manufacturing firms from J-NIS 2009. The authors found that performance-based monetary compensation systems do not have a positive impact on innovation while the introduction of an assessment system based on R&D performance does.

Also of interest in this context is the study by Ederer and Manso (2013), who, using a laboratory experiment, provided evidence that the combination of tolerance for early failure and reward for long-term success is effective in motivating innovation, suggesting that incentive schemes should be designed from a long-term perspective. The results are consistent with the findings by Lerner and Wulf (2007) and Kanama and Nishikawa (2015) that long-term incentives are positively associated with innovation.

Finally, turning to R&D organization structures, several studies investigated whether the choice of a centralized or decentralized R&D structure affects R&D outcomes. Argyres and Silverman (2004), using a sample of 71 large research-intensive corporations, showed that firms with centralized R&D labs generate more highly cited patents than firms with decentralized structures. Lerner and Wulf (2007), focusing on the relationship between innovation and compensation of corporate R&D heads with a sample of 500 firms listed by Fortune, found that more long-term incentives are associated with innovation in firms with centralized R&D organizations while no association in firms with decentralized R&D organizations was found. These studies suggest that firms with a centralized R&D organization tend to generate more frequently cited patents.

Most of the studies mentioned employed patent citation data to measure innovation outcomes. Azoulay and Lerner (2013) noted that patents are direct outcomes of firms' innovation activities. However, patent citations represent neither the relevance of the research to the firm's product market nor the role of management practices in the successful commercialization of innovation. A better proxy for the relevance of research outcomes is the sales from innovative products. Moreover, some management practices may be complementary, and the choice of management practices is potentially endogenous. Previous studies provide suggestive conditional correlations, not estimates of causal effects. In addition, HRM and organization management practices have complimentary effects; however, such complementarities are not sufficiently explored in previous studies. The internal organization of innovating firms still represents a black box, and knowledge on the management of the impact of each management practice is still limited. Many questions related to the effects of OHRM practices on innovation remain.

6.3 Japanese Firms' Patent Application and Human Resource Management Practices

6.3.1 Data

In the following sections, by focusing on OHRM issues, I examine the factors affecting the likelihood that firms innovate using a large-scale firm-level dataset on innovation. Specifically, this chapter investigates complementarities among various management practices and identifies which management practices are strongly associated with innovation outcomes.

The data used in this study are firm-level data from the J-NIS.[3] The survey is based on the Oslo Manual and provides a wide range of information on firms' innovation activities and their outcomes, such as the sale of products that embody innovations new to the firm or the market.

The J-NIS was conducted in 2003, 2009, 2012, and 2015, and the data collected in the 2003, 2009, and 2012 surveys were available for academic research at the time this study was conducted. However, each survey is considerably different in sample size and size distribution of responding firms.[4] Moreover, the questions and choices provided for answers were also different, although all the surveys are based on the Oslo Manual. This means that only the J-NIS 2009 extensively surveys HRM of researchers and organizational management of research units/divisions, while the 2003 and the 2012 J-NIS focus more on organizational management of the entire firm. Therefore, this study uses the J-NIS 2009 data. In addition, for the empirical analyses, I eliminated observations on firms that did not provide information on their total sales amount. Consequently, 3,837 observations remained for the year 2009. Table 6.1 shows the number of firms by industry. Although more detailed (3-digit level) industry information is available, this study classifies firms into 11 manufacturing industries and 7 nonmanufacturing industries. A sample for this study includes 1,589 manufacturing firms (41.4%) and 2,248 firms that fall into the nonmanufacturing industry category (58.6%).

6.3.2 Overview of Patent Applicants and Innovation Activities

J-NIS contains rich information on firms' innovation activities. One of the greatest advantages of using J-NIS is the ability to define firm-level innovation output as the successful introduction of new products or sales from innovation products, such as

[3]The statistical analysis of the firm-level data was conducted by the First Theory-Oriented Research Group, National Institute of Science and Technology Policy (NISTEP), Ministry of Education, Culture, Sports, Science and Technology (MEXT) under arrangements that maintain legal confidentiality requirements. The firm-level data from this national survey are available to researchers for academic research purposes. There is no restriction on who can apply to use the data if it is for academic purposes, but researchers must provide the necessary documents, and the data cannot be taken out of Japan.

[4]Although for all of the surveys the questionnaire was sent out to a sample of firms with ten or more employees, the size distribution of the sample firms differs across surveys. In the 2003 survey, 19% of the firms that answered were large firms (250 or more employees) while in the 2009 survey, 48% were large firms. It is possible to construct a panel consisting of firms that responded to all three surveys but, unfortunately, there are few such firms, and the number of observations is insufficient. For more details on the 2003, 2009, and 2012 J-NISs, see the National Institute of Science and Technology Policy (2004, 2010, 2014).

Table 6.1 Number of firms by industry

Industry	ISIC Rev. 3.1	Number of firms
Manufacturing		1589
Food products and beverages, tobacco products	15–16	121
Textiles; wearing apparel; dressing and dyeing of fur; tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harnesses, and footwear	17–19	104
Wood and products of wood and cork, except furniture; articles of straw and planting materials; paper and paper products; publishing, printing, and reproduction of recorded media	20–22	141
Coke, refined petroleum products, and nuclear fuel; Chemicals and chemical products	23–24	134
Rubber and plastics products	25	102
Other nonmetallic mineral products	26	62
Basic metals and recycling; fabricated metal products, except machinery and equipment	27–28, 37	201
Machinery and equipment n.e.c	29	156
Office, accounting, and computing machinery; electrical machinery and apparatus n.e.c; radio, television, and communication equipment and apparatus; medical, precision, and optical instrument, watches and clocks	30–33	335
Motor vehicles, trailers, and semi-trailers. Other transport equipment	34–35	167
Furniture, n.e.c	36	66
Nonmanufacturing		2248
Agriculture, hunting and forestry, fishing, mining and quarrying	1–2, 5, 10–11, 13–14	104
Electricity, gas, heat supply, and water	40–41	275
Wholesale and retail trade; repair of motor vehicles	50–52	825
Transport, storage, and postal services	60–64	327
Telecommunications	64	246
Financial intermediation	65–67	163
Real estate; rental, and leasing activities; business services	70–74	308
Total		3837

realizing product/process innovations, effects of innovations, or sales of new-to-the-firm innovations.

Patents are a common proxy for direct outcomes of firms' innovation activities, and they have been used in previous research as detailed in Sect. 6.2. For HRM, firms might use patents as an evaluation for personnel assessment or incentive payment schemes for researchers. Because the information on patents is excluded from the J-NIS, how many patents were applied by innovating firms or how many applicants were applied by innovating firms is unknown. This chapter combined the data from J-NIS 2009 and the IIP Database to examine the relationship between firms' management on effective R&D and patenting activities.

This chapter uses the information of patents applications submitted to the Japan Patent Office during the period from 2006 to 2008, responding to the J-NIS 2009. The database is called the IIP Database constructed by the Institute of Intellectual Property, a research institute based in Tokyo, and the methodology for the construction is based on Goto and Motohashi (2007). Tracing the innovation activities and patenting of firms, this chapter first matched the patent application number in the IIP Database with innovation activities of the corresponding firm number in the J-NIS 2009. A total of 94,469 patents were submitted from 700 of 3,837 sample firms. This subsection summarizes the information on the patents submitted by the firms of the J-NIS 2009 and then examines the characteristics of the firms' innovation activities based on the results of the J-NIS 2009.

Table 6.2 shows the number of firms that applied for patents by industry. The first category in Table 6.2 indicates that 68.5% of total firms were classified as manufacturing industry firms. The second and third categories in the table indicate the number of firms that applied for patents independently and jointly and independently only, respectively. Seven hundred firms from J-NIS 2009 applied for patents from 2006 to 2008. Five hundred and sixty firms applied independently for patents, whereas 515 firms co-applied for patents; 185 firms (26.4%) only applied independently for patents, and 140 firms (20.0%) only co-applied for patents, and 375 firms out of 700 firms (53.6%) applied for patents both independently and jointly. The share of firms applying for patents by themselves as well as jointly with research partners is 40–63.5% in manufacturing industries, which is much larger than for firms with other activities.

Iwasa and Odagiri (2004) investigated the contribution of R&D at home and abroad to firms' inventing activity using a sample of 137 Japanese multinationals and noting the extent that the firm can gain from external technological knowledge, which is determined by the interaction of several factors. One important factor is absorptive capacity, that is, the capacity to scan, evaluate, and assimilate the technological knowledge to be integrated. Thus, for successful innovation, firms have a sufficient absorptive capacity with a certain level of prior related knowledge accumulated through their own R&D. Considering the number of patent applications per firm, firms may conduct research collaboration to use external knowledge for challenging themes in conducting their own research projects. I expect that 53.6% of the targeted 700 firms apply for patents independently and jointly with research partners as innovation outputs according to their R&D strategies.

Though the share of those firms is over 50% of targeted firms (Table 6.2), the total amount of the co-applied patents is small. Table 6.3 shows the number of patent applicants from 2006 to 2009. Table 6.3 indicates that 94,469 patents were submitted during the period, and the share of patents applied for with more than one partner was 15.7% (=100 − 84.3). The number was small compared to independently applied patents. Tables 6.2 and 6.3 imply that a large number of Japanese innovating firms filed singly and jointly; however, the greatest number of patent applications were independent submissions.

Table 6.2 Number of firms applying for patents by industry

Industry	Number of firms	Number of firms applying patents independently and jointly	Number of firms applying patents independently only
Manufacturing	480	279 (58.1%)	120 (25.0%)
Food products and beverages, tobacco products	19	11 (57.9%)	2 (10.5%)
Textiles. Wearing apparel; dressing and dyeing of fur. Tanning and dressing of leather manufacture of luggage, handbags, saddlery, harness, and footwear	22	12 (54.5%)	6 (27.3%)
Wood and products of wood and cork, except furniture; articles of straw and planting materials. Paper and paper products. Publishing, printing, and reproduction of recorded media	21	9 (42.9%)	9 (42.9%)
Coke, refined petroleum products, and unclear fuel. Chemicals and chemical products	54	34 (63.0%)	11 (20.4%)
Rubber and plastics products	40	26 (65.0%)	7 (17.5%)
Other nonmetallic mineral products	22	14 (63.6%)	5 (22.7%)
Basic metals + Recycling. Fabricated metal products, except machinery and equipment	81	50 (61.7%)	18 (22.2%)
Machinery and equipment n.e.c	63	40 (63.5%)	16 (25.4%)
Office, accounting, and computing machinery. Electrical machinery and apparatus n.e.c. Radio, television, and communication equipment and apparatus. Medical, precision, and optical instrument, watches and clocks	100	54 (54.0%)	26 (26.0%)
Motor vehicles, trailers, and semi-trailers. Other transport equipment	35	14 (40.0%)	14 (40.0%)
Furniture, n.e.c	23	15 (65.2%)	6 (26.1%)
Nonmanufacturing	220	96 (43.6%)	65 (29.5%)
Agriculture, hunting and forestry, fishing, mining and quarrying	2	0 (0.0%)	0 (0/0%)
Electricity, gas, heat supply, and water	58	28 (48.3%)	11 (19.0%)
Wholesale and retail trade; repair of motor	67	35 (52.2%)	24 (35.8%)
Transport, storage, and post	10	4 (40.0%)	1 (10.0%)
Telecommunications	8	2 (25.0%)	2 (25.0%)
Financial intermediation	9	2 (22.2%)	6 (66.7%)
Real estate, renting, and business activities	66	25 (37.9%)	21 (31.8%)
Total	700	375 (53.6%)	185 (26.4%)

Table 6.3 Patent counts by the number of applicants from 2006 to 2008

Number of patent applicants	Number of patents
1	79640 (84.30%)
2	11625 (12.31%)
3	2736 (2.90%)
4	290 (0.31%)
5	53 (0.06%)
6	51 (0.05%)
7	10 (0.01%)
8	3 (0.00%)
9	37 (0.04%)
10	7 (0.01%)
11	2 (0.00%)
12	11 (0.01%)
13	2 (0.00%)
14	2 (0.00%)
Total	94469

This raises the question: What type of research partners, as sources of external knowledge, do firms look to partner with for co-patent application? The number of patents jointly submitted by 700 targeted firms was 14,829. I examined co-applicant information for each patent and classified the patents into eight categories shown in Table 6.4, identified by firm name and their business description.[5] Table 6.4 provides information on targeted firms and their engagement with the various types of innovation partners. Although many of the patents were submitted with other enterprises, the share of applied patents with at least one other applicant in the following seven categories was approximately 16%. Particularly, the patents submitted with nonprofit research institutes such as universities, higher education institutions, or/and governmental institutions or research organizations were approximately 9.5% (=6.55 + 2.94) of co-applied patents.

For R&D for science-based innovation, for example, in medical devices and clinical applications, collaboration with healthcare professionals working at medical institutions and universities is necessary for the development of future technologies corresponding to the latest global healthcare trends and clinical needs. Clinical evaluation studies and investigations in cooperation with medical facilities, academic publications, and scientific presentations are necessary to accept the validity

[5]The first category includes subsidiaries and enterprise group membership. The second category consisted of patents submitted with university or higher education institutions. Because applicants who engaged in university laboratories applied for patents as an individual and not as a university laboratory, the number of patents submitted by universities must be underestimated. I thus modified the number using the information on partners for innovation from the J-NIS 2009 and using the mailing address of individual patent applicants. The sixth category includes overseas enterprises and universities. The seventh category excludes individuals who belonged to university laboratories.

Table 6.4 Number of patents by categories of co-applicants from 2006 to 2008

Co-applicants	Number of patents
Other enterprises	12476 (84.13%)
Universities, higher education institutions	971 (6.55%)
Governmental institutions and research organizations	436 (2.94%)
Consultants, commercial laboratories/R&D enterprise/research institutes	1223 (8.24%)
Prefectural/municipal/provincial governments	96 (0.65%)
Overseas enterprises	182 (1.23%)
Individual person/association	222 (1.50%)
Foundations/incorporated associations	302 (2.04%)
Total number of patents which jointly applied	14829

Notes: Some co-applicants (e.g., a university abroad) are in more than one category. Some patents include various types of co-applicants. Therefore, the total number is much larger than the total number of patents with more than two applicants shown in Table 6.5

of new technologies. Toshiba Medical System Corporation (TMSC), which is one of the affiliated companies of Japanese major industrial/consumer electronics manufacturer Toshiba Corporation, conducts collaborative research with Kobe University for new clinical application software, image analysis technologies, and imaging methods to integrate the technologies owned by TMSC, Toshiba Corporation, and other overseas affiliated companies with Kobe University's image analysis technologies and clinical experience. Their joint research in 2004, for instance, was three-dimensional, computer-aided diagnosis (CAD), followed by clinical application software for organs/lesions using Aquilion ONE and an optical imaging method for trunk regions using Toshiba's 3-tesla magnetic resonance imaging (MRI) systems Vantage Titan 3T. Because of the joint research, TMSC has successfully introduced a variety of products based on these outcomes and produced many joint inventions (Tachizaki 2015).

As the example of TMSC's joint research indicates, I suspect that innovating firms tend to access more advanced or different types of external knowledge, although the number of patents submitted with outside partners is smaller than in Table 6.3.

J-NIS 2009 provide a more in-depth look at the differences between the firms applying for patents and the firms that are not applying for patents. Table 6.5 provides summary statistics on the innovation activities of Japanese firms based on the 2009 survey. Most of the variables in Table 6.5 are dummy variables that take one if an observation applies. The first category, consisting of firms that applied for patents during the period 2006–2008, indicates innovation activity by the firms. The table shows that 80% of firms that applied for patents were large firms and more likely to innovate than firms without patenting activities. For innovation output,

Table 6.5 Characteristics of innovation by patent application: means of variables

	Patent application in 2006–2008 = Yes	Patent application in 2006–2008 = No	Overall average
Knowledge/Innovation			
R&D intensity (internal R&D expenditure/sales in 2006) (%)	1.43	0.51	0.67
Innovator (product and/or process innovation) [0/1]	0.78	0.42	0.49
Product innovation [0/1]	0.65	0.24	0.32
Process innovation [0/1]	0.61	0.34	0.39
Amount of sales with new products (million yen; only firms with product innovation)	5579.15	506.08	1431.58
Cooperation for innovation with other firms and institutions [0/1]	0.64	0.22	0.29
Cooperation for innovation with foreign firms and institutions (only for firms with cooperation for innovation) [0/1]	0.20	0.04	0.07
Public support			
Local funding [0/1]	0.10	0.04	0.05
National funding [0/1]	0.17	0.03	0.06
Effects regarding product innovation (only for firms with product innovation)			
Increased the range of goods and services: medium or light importance [0/1]	0.44	0.15	0.20
Expanded the market or increased market share: medium or high importance [0/1]	0.29	0.11	0.15
Improved quality in goods or services: medium or high [0/1]	0.42	0.15	0.20
Effects regarding process innovation (only for firms with process innovation)			
Improved production flexibility: medium or high importance [0/1]	0.29	0.13	0.16
Reduced labor cost: medium or high importance [0/1]	0.12	0.07	0.08
Reduced materials and energy usage: medium or high importance [0/1]	0.09	0.06	0.07
Other effects (only firms with product and/or process innovation)			
Improved environment and impact or health and safety aspects: medium or high importance [0/1]	0.29	0.12	0.15
Satisfied regulations or standards: medium or high importance [0/1]	0.38	0.19	0.22

(continued)

Table 6.5 (continued)

	Patent application in 2006–2008 = Yes	Patent application in 2006–2008 = No	Overall average
Sources of information			
Internal sources within the group [0/1]	0.60	0.22	0.29
Suppliers as source of information [0/1]	0.47	0.20	0.25
Customers as source of information [0/1]	0.54	0.18	0.25
Competitors as source of information [0/1]	0.27	0.10	0.14
Universities or government as source of information [0/1]	0.40	0.08	0.14
Appropriability conditions			
Formal protection [0/1]	0.50	0.08	0.15
Strategic protection [0/1]	0.54	0.18	0.25
Firm size			
10–49 employees [0/1]	0.05	0.31	0.26
50–249 employees [0/1]	0.14	0.29	0.26
250 or more employees [0/1]	0.81	0.40	0.48
Observations	700	3137	3837

Notes: Items with [0/1] are based on dummy variables that take one for firms that apply and zero otherwise. Therefore, the mean values shown in the table for such items indicate the share of firms that apply

for example, the propensity to be an innovator measured by the amount of sales of new products, the share of firms that realized product or process innovation, was larger for firms with patent applications. For innovation inputs, the average R&D intensity was greater for this category of firms, for example. Another notable observation is that firms with patent applications were considerably more likely to have a cooperation agreement on innovation with other firms and industries and with foreign firms and institutions. These firms, moreover, were more likely to receive central government-funded public financial support for innovation activities and to use variable sources of information such as customers, universities, or government.

For the effects of innovation, firms with patent applications were more likely to increase the range of goods and service and place emphasis on improving the quality of goods and service than firms without patent applications. For the appropriability condition, firms with patent applications were more likely to use formal protections including intellectual property rights and strategic protections such as trade secrets, complexity of design, or advantages over competitors in lead time. The results imply that firms with patent applications tend to use other complementary ways and means to obtain greater profit from innovation.

6.3.3 Overview of Firms' Patent Applications and R&D Organizational Design

For internal factors affecting firms' innovation activities, patent applications are a direct outcome of innovation activities in this study, and I focus on OHRM within a firm. This section overviews the effect of HRM on the innovation of firms with patent applications.

J-NIS 2009 asked 11 questions regarding OHRM to promote efficient R&D activities during the preceding 3 years. For simplicity, I aggregate the 11 questions into eight items and group them into three broad categories. Categories O1 and O3 are related to narrowly defined organizational management while category O2 is related to HRM:

O1) *Cooperation and coordination across business units or divisions at the firm overall*

- Interdivisional cooperation/teams: The firm implemented employee rotations across divisions or created project teams across divisions.
- Interdivisional meetings/systems: The firm held meetings across divisions or introduced systems that accumulate, exchange, or share information across divisions.

O2) *R&D personnel human resource management*

- Board members with an R&D background: The firm assigned a person from the R&D division as a board member.
- Personnel assessment reflecting R&D outcomes: The firm reflected R&D outcomes in the assessment of researchers or engineers.
- Incentive payments: The firm employed an incentive payment scheme to reward inventions by employees.
- Employment or reemployment of retired researchers or engineers: The firm employed or reemployed researchers or engineers who had reached retirement age.

O3) *Restructuring of R&D organization*

- Creation/relocation/integration/reorganization of R&D centers or divisions: The firm created, relocated, integrated, or reorganized centers or divisions of the firm's R&D activities.
- Increased authority for researchers/engineers: The firm increased or extended the authority of researchers or engineers.

Table 6.6 shows the number of firms that answered affirmatively to questions related to the above management practices. The firms are further divided into two groups: firms that applied for patents in the preceding 3 years and firms that did not. First, to broadly capture the characteristics of management practices for Japanese

Table 6.6 Number of firms conducting a combination of three broad categories of organization management (total = 3837)

Combination (O1, O2, O3)	Patent application in 2006–2008 = Yes	Patent application in 2006–2008 = No
	700 (100.0%)	3137 (100.0%)
None (0, 0, 0)	124 (17.7%)	1544 (49.2%)
One	109 (15.6%)	824 (26.3%)
(1, 0, 0)	87 (12.4%)	721(23.0%)
(0, 1, 0)	19 (2.7%)	91 (2.9%)
(0, 0, 1)	3 (0.4%)	12 (0.4%)
Two	229 (32.7%)	558 (17.8%)
(1, 1, 0)	197 (28.1%)	469 (15.0%)
(1, 0, 1)	26 (3.7%)	81 (2.6%)
(0, 1, 1)	6 (0.9%)	8 (0.3%)
All (1, 1, 1)	238 (34%)	211 (6.8%)

firms, I identify the number of firms that implemented at least one practice for each of the three categories, O1, O2, and O3.

Table 6.6 lists various combinations of management practices and summarizes the number of firms by each combination. The combination (1, 0, 0), for example, represents a pattern where a firm implements at least one of the two practices from category O1 but does not implement any practices from categories O2 and O3. Similarly, the combination (0, 1, 1), for example, represents a pattern where a firm does not implement any practices from category O1 while it implements at least one practice from category O2 and at least one practice from category O3. Table 6.6 shows that the majority of the firms that did not apply for patents (49.2%, 1,544 firms out of the 3,137 firms without patent applications) did not implement any of the management practices listed in any of the three categories, that is, the combination (0, 0, 0), while most of the firms with patent applications (82.3%, i.e., 100 − 17.7%) implemented at least one of the management practices. Table 6.6 shows that firms with patent applications were much more engaged in OHRM.

However, practices from the category O1 (cooperation across business units at the firm level) were popular even among firms without patent applications; 1,959 (=721 + 558 + 469 + 211) firms out of the 3,137 firms without patent applications (62.4%) implemented at least one practice from category O1 while 868 (=91 + 558 + 8 + 211) and 312 (=12 + 81 + 8 + 211) firms implemented at least one of the practices from categories O2 and O3, respectively. Thus, the number of firms that implemented practices in the O3 category, "Restructuring R&D organization," was much smaller than the number of firms that implemented practices in the O2 category, "Human resource management," particularly in the case of firms without patent applications. Restructuring R&D organization might be a less important practice or a more difficult practice than HRM.

More importantly, a significant number of firms implemented practices from more than one category, particularly in the case of firms with patent applications;

Table 6.7 Characteristics of innovation by patent application

Number of firms (total = 3837)		
	Patent application in 2006–2008 = Yes	Patent application in 2006–2008 = No
Total number of firms	700 (100.0%)	3137 (100.0%)
Ways of organization management		
O1) Cooperation across business units		
Interdivisional cooperation/teams	431 (61.6%)	1016 (32.4%)
Interdivisional meetings/systems	524 (74.9%)	1380 (44.0%)
O2) Human resource management		
Board members with R&D background	165 (23.6%)	127 (4.0%)
Personnel assessment reflecting R&D outcome	294 (42.0%)	276 (8.8%)
Incentive payment	314 (44.9%)	294 (9.4%)
Employment or reemployment of retired researchers or engineers	268 (38.3%)	493 (15.7%)
O3) Restructuring R&D organization		
Creative/relocation/integration of R&D centers	260 (37.1%)	257 (8.2%)
Increased authority for researchers/engineers	60 (8.6%)	111 (3.5%)

229 firms (32.7%) out of the 700 firms with patent applications implemented practices from two out of the three categories, and 238 firms (34%) implemented practices from all three categories while 109 firms (15.6%) implemented practices from only one of the three categories. However, for firms without patent applications, the number and share of firms that implemented practices from all three categories is 211 firms (6.8%), which is small. The fact that a substantial share of firms with patent applications implemented all three types of management practices simultaneously suggests that all three categories are potentially important for greater efficiency of R&D activities, and there may be some complementarities among the different management practices.

Table 6.6 focused on the three broad categories of OHRM, O1, O2, and O3, and presumed that such management practices are positively associated with patent applications. Table 6.6 also indicated that implementing different types of management practices simultaneously is important for innovation outputs, for example, patent applications. I thus examine each management practice in more detail. As described in this subsection, there are two to four detailed management practices included in each of the three management categories, O1, O2, and O3. Table 6.7 shows the number of firms that implemented each of the management practices included in the three categories. The firms are further divided into two groups: firms that applied for patents from 2006 to 2008 and firms that did not.

Table 6.7 shows that both practices from category O1, "Cooperate across business units," are implemented by many firms, even by firms without patent applications. However, for category O2, for example, HRM, there is a clear difference between firms with patent applications and firms without. For firms with patent applications, the number of implementing firms was relatively evenly distributed among the three practices, for example, personnel assessment reflecting R&D outcome, incentive payments, and employment or reemployment of retired researchers or engineers. However, for firms without patent applications, employment or reemployment of retired researchers or engineers was more popular than other practices, and the personnel assessment reflecting R&D outcome was less popular. Table 6.7 also indicates that for firms without patent applications, the number of firms that implemented the two practices from category O3, "Restructuring R&D organization," was much less than the number of firms that implemented practices from the other categories O1 or O2 while a substantial number of firms implemented practices from category O3 in the case of firms with patent applications.

Tables 6.6 and 6.7 show results that correspond to the case of Japanese firms. Given the example of Shiseido in the introduction of this chapter, the creation/relocation/integration/reorganization of R&D centers or divisions might be required to improve R&D productivity with the implementation of HRM. Another example, Takeda Pharmaceutical Company, is a global, research-driven pharmaceutical company that focuses R&D efforts on oncology, gastroenterology, and central nervous system therapeutic areas plus vaccines. Takeda conducts R&D both internally and with partners globally to stay at the leading edge of innovation. Christophe Weber became the new CEO for New Takeda in 2015 and has experience in pharmaceutical marketing for emerging countries. Weber implemented R&D personnel HRM over diverse nationalities with mixed experience. Moreover, Takeda announced plans to accelerate the R&D organization transformation by reinforcing three therapeutic areas and concentrating R&D activities in Japan and the USA. The transformation is considered critical to provide the company with the necessary organization and financial flexibility to drive innovations, enhance partnerships, and improve R&D productivity for long-term, sustainable growth. Takeda will optimize its R&D sites globally to build a world leading R&D organization and pipeline.[6]

Unfortunately, I do not have access to detailed information on each practice; however, these figures imply that there are significant differences in management practices between firms with patent applications and firms without. The difference might be caused by a necessity for HRM of R&D personnel to innovate; firms are initially not designed to apply for patents and thus fail to implement performance-based assessment applications. I conjecture that the difference should determine innovation outcome at the firm level while further investigation of this causal relationship represents another important subject for research.

[6]For more details, see the Nikkei website July 30, 2016: http://www.nikkei.com/ (accessed on September 20, 2016).

6.4 Concluding Remarks

This chapter elucidates the relationship between firms' innovation outcomes and the organizational design of R&D activities including HRM within a firm. First, this chapter reviews the related literature on the interaction between OHRM and innovation. The chapter then focuses on the following three types of management practices: (1) cooperation and coordination across firm business units or divisions overall, (2) R&D personnel HRM, and (3) restructuring the organization of R&D. This study focuses on patent applications as a direct innovation outcome and overviews the characteristics of Japanese firms' OHRM practices and patent applications by combining two datasets from the J-NIS 2009 and the IIP Database.

Based on the databases in this chapter, although the number of jointly submitted patents is smaller than the number of independently applied patents, I found that over 50% of firms with patent applications conducted innovation activities with other partners; firms co-applications tend to utilize various knowledge sources, particularly those with enterprises, universities, or higher education facilities as innovation partners. This chapter shows that firms with patent applications and firms without differ in their innovation activities; firms with patent applications use more innovation inputs and generate more innovation outputs. Firms with patent applications are larger in size, conduct more R&D, and use diverse sources of information for innovation. Similarly, firms with patent applications are more innovative with products and processes and show greater profits or results from innovation.

For OHRM of R&D activities, a significant number of firms with patent applications implemented more than one category of the three management practices, for example, (1), (2), and (3) in Sect. 6.3.3. Because firms with patent applications are much more involved in the three management categories of OHRM, I conjecture that there are some complementarities among various management practices. For the three management categories, firms with patent applications implemented personnel management and restructured R&D organization to a greater extent than firms without patent applications.

Generating value from innovation is much harder today for Japanese firms, particularly in the last two decades. Firms must reform their OHRM in accordance with recent changes in the functions of the central research institute, incentives to innovate, the attribution of invention to researchers, and the expansion of internal and external R&D. I am certain that this chapter indicates the importance of OHRM and identifies which management practices are more effective for efficient R&D by Japanese firms using quantitative information such as data from the J-NIS and IIP databases. The finding of this chapter must be useful for R&D managers/researchers/engineers in business.

Because I did not conduct an econometric analysis, further analysis using the information gained from the surveys is necessary to estimate the interrelation in detail between innovation outcome and organizational design of R&D activities. Analysis investigating the organizational management between firms with independent patent applications and those with joint applications is also necessary for further investigation. Given various data limitations, there is no detailed information on the assessment or payment system for each firm in this chapter. Similarly, this chapter does not address to what extent the wage level reflects the result of personnel assessment, which may affect researchers' motivation and change the rate and direction of innovation. Moreover, this chapter does not provide details on R&D organizational changes: whether an R&D center is closed, relocated, or integrated. Filling the gap between a quantitative analysis and a detailed case study would be necessary to understand the relationship between organizational designs of R&D activities.

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