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Research paper

Organizational and human resource management and innovation: Which management practices are linked to product and/or process innovation?

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ABSTRACT

We examine the determinants of firms' innovation success, using the firm-level data from the Japanese National Innovation Survey. We focus on the relationship between organizational and human resource management practices for research and development (R & D) and product/process innovation. We find that interdivisional cooperation/teams and the creation/relocation/integration of R & D centers are positively associated with both product and process innovation. Having board members with an R & D background is positively associated with product innovation, implying that top-down R & D decision-making may be important for firms to introduce new products. Among the factors examined, personnel assessment reflecting R & D outcomes appears to have an especially strong relationship with product innovation. Moreover, the positive relationship between the creation/relocation/integration of R & D centers and innovation success suggests that drastic organizational changes can work as a clear signal of firms' determination to pursue an innovation-oriented strategy and help to accelerate innovation success.

1. Introduction

Innovation has long been recognized as the most important source of economic development and firms' growth (Schumpeter, 1934; Penrose, 1959). Consequently, how to boost innovation has been of central interest to both policy makers and entrepreneurs.

In the academic field, market competition is considered to be an important determinant of firms' incentive to innovate, and research examining the relationship between competition and innovation both from a theoretical and an empirical perspective spans back more than half a century (e.g., Arrow, 1962; Gilbert and Newbery, 1982; Cohen and Levin, 1989; Aghion et al., 2005; Vives, 2008). However, the degree of competition among firms in a particular product market is not necessarily the main or key factor determining the probability of innovation success.

Teece (1996), for instance, argues that an important determinant of innovation is firm organization and that scholars need to understand the importance not only of market structure and the business environment but also of the formal and informal structures of firm organization. There is some quantitative evidence indicating that such organizational aspects indeed are important determinants of innovation inputs and output. For example, estimating patent production functions, Pakes and Griliches (1984) found that the magnitude of the coefficient on research and development (R & D) investment fell drastically when firm-specific effects are controlled for. Meanwhile, Scott (1984) found that firm fixed effects explained about 50% of the variance in R & D intensity. These results imply that there are unobserved firm-specific factors which greatly affect innovation activities. One possible explanation of the results is that firm-specific organizational practices play a role in determining firms' innovation output and inputs.

Against this background, the literature has increasingly focused on various features of organizations, including (1) the design of incentive systems; (2) firms' ability to manage spillovers of knowledge; and (3) firms' choice of organizational structure. However, although there is a burgeoning literature on organizational and human resource management issues (for a survey, see, e.g., Bloom and Van Reenen (2011), Laursen and Foss (2014), and Seeck and Diehl (2017)), most studies do not focus on management practices for R & D units or R & D personnel. Instead, they investigate, for example, the relationship between innovation and firm-wide management practices such as the role of teams, payment schemes, and training for workers overall, without specifically focusing on management practices with regard to researchers and/or research units.

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Yet, as pointed out by Azoulay and Lerner (2013), most of our knowledge on this relationship does not stem from the mining of traditional datasets such as large sample survey datasets or census-type datasets, but from small-sample surveys and case studies. Moreover, previous empirical studies using firm-level innovation survey data or patent-inventor linked data, as we will detail in the next section, have not yet provided conclusive evidence on the relationship between R & D human resource management and R & D outcomes.

This means that there are still very few empirical examinations of organizational management and R & D activities based on large-scale firm-level databases.[1] Moreover, as the literature surveys by Laursen and Foss (2014) and Seeck and Diehl (2017) highlight, the possible differential roles of management practices depending on the phase of the innovation process or the type of innovation, i.e., product or process innovation, have not yet been sufficiently investigated in previous empirical research.

Therefore, the aim of the present study is to empirically examine the relationship between firms' R & D-related organizational and human resource management on the one hand and innovation output on the other hand. For the analysis, we use the firm-level data underlying the Japanese National Innovation Survey conducted by the Ministry of Education, Culture, Sports, Science and Technology in 2009. This survey is the Japanese equivalent of the Community Innovation Surveys (CIS) conducted by the European Union. Using the data enables us to define two different types of firm-level innovation output: product innovation, which is defined as the successful introduction of new products or sales from innovative products; and process innovation, which is defined as the successful introduction of new or significantly improved production processes. The data also enable us to take the technological superiority of product innovations (breakthrough innovation) into account by using information on the time required by rivals to catch up. Moreover, using the data, we can obtain firm-level information on within-firm R & D organizational changes as well as on assessment schemes for researchers. The novelty of our study is that it examines the link between the management of researchers or research units and firm-level innovation using firm-level information on innovative products/processes. Moreover, we examine whether there is a difference in the link between management practices and innovation depending on the type of innovation. We explicitly investigate what kinds of management practices are positively associated with product or process innovation and breakthrough product innovation.

Our findings suggest that implementing more than one management practice at the same time is associated with a higher probability of innovating new products. Particularly for product innovation, management practices such as interdivisional cooperation, board members with an R & D background, personnel assessment reflecting R & D outcomes, and restructuring of R & D centers have a strong and positive link with innovation success. Among these practices, personnel assessment appears to have an especially strong relationship with product innovation. However, in the case of process innovation, human resource management practices are less likely to be significantly positively linked with innovation success. Meanwhile, the importance of board members with an R & D background and the restructuring of R & D centers suggests that top-down R & D decision making and drastic organizational changes can serve as a definitive signal of firms' intent to pursue an innovation-oriented strategy and can accelerate innovation success.

The remainder of this study is organized as follows. Section 2 provides a survey of the related literature and highlights the importance of organizational factors as determinants of innovation success. Based on the literature review, we present our hypotheses on the link between various management practices and success in product/process innovation. Section 3 describes the dataset used in this study and discusses various characteristics of the innovation management practices of Japanese firms. Section 4 then examines complementarities between organizational and human resource management practices. Next, Section 5 explores effective management practices in more detail and investigates practices particularly effective for breakthrough innovation. Finally, Section 6 concludes.

[1] A few exceptions which analyze the relationship between internal organization and R & D activities using firm-level data include Laursen and Foss (2003), Argyres and Silverman (2004), Lerner and Wulf (2007), Arora et al. (2014), and Kanama and Nishikawa (2017).

2. Related literature

Teece (1996) argues that the formal and informal structures of a firm have an important bearing on the strength of innovation activity. He highlights seven key properties of technological innovation. Specifically, innovation tends to be characterized by uncertainty, path dependency, and technological interrelatedness, it tends to be cumulative in nature and exhibit irreversibilities, knowledge is often tacit, and innovations can be difficult to appropriate. Given these underlying properties of technological innovation, he identifies 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, in order to attain economies of scope and successfully commercialize innovations; and (4) human resource management practices to develop corporate norms and instill them in employees.

Based on Teece's (1996) discussion, this study – mainly reflecting data availability – focuses on the following three broad types of management practices: (1) cooperation and coordination across business units or divisions at the firm as a whole; (2) human resource management with regard to R & D personnel; and (3) restructuring the organization of R & D. The remainder of this section reviews findings of previous empirical studies related to these types of management practices.[2]

2.1. Cooperation and coordination across business units or divisions

First, cooperation and coordination across business units or divisions is expected to increase knowledge spillovers within a firm and to improve firm performance. As argued by Shipton et al. (2005), for example, transfer of knowledge within an organization is one important stage of the organizational learning cycle through which innovation is promoted. Jones (2009), for example, using a large micro dataset of inventors and focusing on organizational management practices, shows that teamwork becomes more important over time. However, the impact of teamwork may differ depending on team members' cognitive style, i.e., whether the team contains members that are creative, conformist, and/or attentive to detail, etc. Miron-Spektor et al. (2011) find that creative team members are essential for team radical innovation, while attentive-to-detail members had a negative influence on team radical innovation.

2.2. Human resource management

As for human resource management, a topic that has received considerably more attention is the role of incentive systems such as pay for performance. Studies on pay for performance have produced mixed results, however. While some show that compensation based on the pay-for-performance principle induces higher levels of effort and productivity (e.g., Lazear, 2000; Shearer, 2004), other studies highlight the distortions associated with incentive pay schemes (e.g., Bloom and Van

[2] For a discussion of the importance of managing the organizational context when managing innovation, see Phillips (2014).

Reenen, 2011). Meanwhile, using a large micro dataset on inventors, Nagaoka et al. (2014) examine the relationship between revenue-based payments for inventions and research outcomes (proxied by the number of patent citations). They find that although incentive pay schemes tend to increase the number of patent citations (i.e., result in higher-quality inventions), the effect depends on the degree of inventors' intrinsic motivation for science. Intrinsic motivation is based on researchers' enthusiasm for exploration and means that researchers work on something because they find it personally rewarding. On the other hand, monetary incentives provide only extrinsic incentives, and Nagaoka et al. (2014) find that for inventors with greater intrinsic motivation incentive pay schemes have a smaller positive effect. This result is consistent with findings by Stern (2004), who, using a dataset on job offers for postdoctoral biologists, observes a negative relationship between intrinsic and extrinsic incentives.

Studies such as Lerner and Wulf (2007), Yanadori and Cui (2013), and Kanama and Nishikawa (2017) statistically examine the relationship between remuneration schemes and innovation. Lerner and Wulf (2007) analyze the relationship between compensation of senior executives and R & D outcomes and find that more long-term incentives such as stock options are associated with more heavily cited patents. However, Yanadori and Cui (2013), focusing on the compensation of R & D employees, find that pay dispersion among R & D employees is negatively associated with firm innovation (proxied by the number of successful patent applications), which implies that large pay differentials among employees decrease collaboration and preclude innovation. Kanama and Nishikawa (2017), using the same dataset as that employed in our study, also find that monetary compensation does 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, provide 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.

Another aspect that is potentially important is the role of leadership. However, although this aspect has been noted by scholars, there is very little research on the link between leadership and innovation (Oke et al., 2009). Exceptions include studies such as Jung et al. (2003) and Mokhber et al. (2017), which explore the connection between innovation and transformational leadership. Transformational leadership focuses on longer-term and vision-based motivational processes (Bass, 1990). The studies by Jung et al. (2003) and Mokhber et al. (2017) indicate that transformational leader have a positive impact on organizational creativity. Jung et al. (2003) show that transformational leadership by top managers likely creates an organizational culture in which employees are encouraged to freely discuss and try out innovative ideas and approaches.

As for employee diversity, previous studies such as Van der Vegt and Janssen (2003) suggest that employee diversity is positively associated with innovation performance, since innovation is an interactive process where employees interact in groups and develop, discuss, modify, and realize new ideas. However, Østergaard et al. (2011) observe that age diversity has a negative effect on product innovation but find a positive relationship between employee diversity in gender and education on the one hand and product innovation on the other. These findings suggest that differences in perspectives on a wide range of issues between young and old may create disagreement, lowering innovation performance.

2.3. Restructuring the organization of R & D

Turning to R & D organization structures, several studies investigate whether the choice of a centralized or decentralized R & D structure affects R & D outcomes (e.g., Argyres and Silverman, 2004). von Zedtwitz et al. (2014) find that R & D organization, or how firms structure their R & D department, is one of the central components to a firm's approach to managing new product development. Lerner and Wulf (2007) found that more long-term incentives are clearly associated with innovation in firms with centralized R & D organizations while no association in firms with decentralized R & D organizations is found. These studies suggest that firms with a centralized R & D organization tend to generate more frequently cited patents.

Another aspect that one might expect to promote innovation, particularly product innovation, is increased authority for researchers to provide intrinsic motivation to researchers to produce creative ideas (see, e.g., Jung and Sosik, 2002). However, Jung et al. (2003) suggest that the effect of empowering researchers to innovate depends on the strength of employees' "perceived" empowerment; i.e., such authority must give researchers a sense that they are in control.

2.4. Product or process innovation

So far, we have focused on the findings of previous studies on product innovation and management practices. However, it is possible that the determinants of innovation differ between product and process innovation, as suggested by Rouvinen (2002) among others, implying that effective management practices are also likely to differ between the two types of innovation. Shipton et al. (2005), for example, find that appraisal systems closely linked to remuneration have a tendency to negatively affect innovation, and that this is particularly so in the case of process innovation. Incremental or process innovation are often associated with learning-by-using or learning-by-doing that accompany the introduction of new machinery, meaning that it is probably more difficult to identify who contributes to successful innovation in the case of incremental or process innovation than in the case of product innovation. It is also likely to be difficult to measure the monetary value of incremental or process innovation, while in the case of product innovation the value is much more easily measured, particularly in cases where the innovation outcome is patented. Such difficulties may reduce workers' incentive to engage in process innovation when a firm introduces monetary incentive schemes.

As for R & D organization, von Zedtwitz et al. (2014) argue that the degree to which R & D projects should be carried out in a decentralized fashion depends on various factors such as the type of innovation and the nature of the project. Centralization is necessary for more radical innovation, while decentralization is possible for incremental innovation. Their argument suggests that centralized R & D organization is more conducive to product innovation while decentralized R & D organization is more conducive to process innovation.

2.5. Complementarity among management practices

Another issue related to the various management practices is the interaction among them. Some management practices may be complementary and the choice of management practices is potentially endogenous. As pointed out in the literature review by Seeck and Diehl (2017), human resource management practices implemented in bundles have an overall positive effect on innovation, while independently implemented practices do not, highlighting the importance of combining complementary human resource management-specific resources. An example is provided by the study by Chen and Huang (2009), which suggests that strategic human resource practices and knowledge management practices are complementary in terms of boosting innovation by enabling firms to acquire external and internal knowledge, sharing and exchanging knowledge among organizational members, and applying knowledge effectively. Their finding also implies that there likely is complementarity between cooperation and coordination across business units and human resource management.

Jung et al. (2003) argue that transformational leadership by the top manager can enhance organizational innovation directly as well as indirectly by creating a climate that supports innovation. Their result also suggests that human resource management is complementary to other organizational management practices such as cooperation and coordination across units and restructuring of R & D organization.

Although quite a few studies underline the importance of combining complementary management practices, theoretical explanations on the underlying mechanisms have not yet been sufficiently explored. Because the definition and/or measurement of management practices vary greatly across studies, systematic theory-testing and development is very challenging (Seeck and Diehl, 2017).

2.6. Hypotheses

Thus, although the relationship between management practices and innovation outcomes has been examined in many previous studies, comprehensive studies that simultaneously look at a variety of management practices are still scarce. Consequently, our knowledge on the magnitude of the impact of each management practice and/or bundles of practices is still limited. That is, little is known about which practices have the largest impact, which combinations of management practices are the most effective, and whether the impact of each practice or bundles of practices differs depending on the types of innovation such as product innovation, breakthrough innovation, or process innovation.

Based on the arguments and findings of the studies reviewed above, we posit the following hypotheses regarding the relationship between various management practices and innovation output:

Hypothesis 1. Cooperation and coordination across business units or divisions at the firm as a whole

Cooperation and coordination across business units or divisions is positively linked with innovation in both products and production processes. However, the strength of the relationship may differ between product and process innovation depending on the cognitive styles of team members.

Hypothesis 2. Human resource management with regard to R & D personnel

As for human resource management, each management practice has a different impact on product and process innovation. Strong leadership and incentive payments are more likely to be positively linked with product innovation than process innovation. Although personnel assessment reflecting R & D outcomes is expected to be positively associated with both product and process innovation, incentive payments may be negatively associated with process innovation. The relationship between age diversity and innovation success is somewhat ambiguous, but is likely to be negative if disagreement among old and young researchers impedes cooperation.

Hypothesis 3. Restructuring the organization of R & D

The optimal structure of R & D organization depends on the type of innovation, the nature of the project, and the possibility of combining resources. That said, restructuring R & D organization in pursuit of optimizing a firm's R & D organization is expected to be positively linked with both product and process innovations. Empowerment of employees is also expected to be positively linked with innovation, particularly product innovation, by providing intrinsic motivation to researchers to produce creative ideas.

Hypothesis 4. Complementarity among management practices

Human resource management practices and organization management practices such as cooperation and coordination across units and restructuring of R & D organization are complementary each other. Therefore, implementing more than one management practice at the same time is expected to be associated with a higher probability of success in both product and process innovations. However, in the case of process innovation, some human resource management practices such as incentive pay and age diversity may not be positively associated with innovation success. Consequently, complementaries among human resource and organization management practices may be weaker in the case of process innovation.

In the following sections, we examine the factors which affect the likelihood that firms innovate, using a large-scale firm-level dataset on product and process innovation. More specifically, we aim to investigate complementarities among various management practices and to examine which management practices are strongly associated with innovation outcomes.

3. Overview of the organizational and human resource management practices in Japanese firms

3.1. Data

The data used in this study are the firm-level data from the Japanese National Innovation Survey (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.

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 the purpose of academic research at the time of writing of this study. However, each survey is considerably different in terms of sample size and size distribution of responding firms.[4] Moreover, the questions and the choices provided for answers were also quite different, although all the surveys are based on the Oslo Manual. This means that only the 2009 J-NIS asks about human resource management for 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. For these reasons, we use the 2009 J-NIS data for this study.

In addition, for our empirical analyses below, we eliminate observations for firms that did not provide information on their total sales amount. As a result, we are left with 3837 observations for 2009. The number of firms by industry is provided in Appendix A Table A1. Although more detailed (3-digit level) industry information is available, we classify firms into 11 manufacturing industries and 7 non-manufacturing industries. Our cross-section database includes 1589 manufacturing firms (41.4%) and 2248 firms that fall into non-manufacturing industries (58.6%).

3.2. Overview of innovative firms and factors that determine firms' innovation behavior

In this study, we focus on product innovation as an outcome of innovation activities. In our dataset, 1218 firms (31.7%) out of the total 3837 firms answered that they successfully innovated new products and/or services in the preceding three years (i.e., 2006–2008 for the 2009 survey).[5]

[3] The statistical analysis of the firm-level data was conducted at 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.

[4] Although in all the surveys, the questionnaire was sent out to a sample of firms with 10 or more employees, the size distribution of the sample firms is very different 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. We could try to construct a panel consisting of firms that responded to all the three surveys. Unfortunately, however, there are very few such firms, so that we do not have a sufficient number of observations. For more details on the 2003, 2009, and 2012 J-NISs, see National Institute of Science and Technology Policy (2004, 2010, 2014).

[5] We closely examined the data in order to check whether the propensity to innovate was affected by the 2007–2008 global economic crisis. While, as mentioned above, the samples across the different survey years differ considerably, so that strictly speaking they are not comparable, we did not find any notable particularities regarding the propensity to innovate in the 2009 survey. For example, comparing the sample of large manufacturing firms (firms with 250 or more employees) across surveys, 54% of such firms in the 2009 survey responded that they successfully innovated new products and/or services, while the corresponding figures in the 2003, 2012, and 2015 surveys are 51%, 44%, and 45%, respectively.

As for internal factors which affect firms' innovation activities, we focus on organizational and human resource management within a firm. The survey asks 11 questions regarding organizational and human resource management for the purpose of efficient R & D activities during the preceding three years. For simplicity, we aggregate the 11 questions into 8 items and group them into 3 broad categories. Categories O1 and O3 are related to narrowly-defined organizational management while category O2 is related to human resource management:

O1) *Cooperation and coordination across business units or divisions at the firm as a whole*

– Interdivisional cooperation/teams: The firm implemented rotation of employees across divisions or created project teams across divisions.
– Interdivisional meetings/systems: The firm held meetings across divisions or introduced systems which accumulate, exchange, or share information across divisions.

O2) *R & D personnel human resource management*

– Board members with 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 re-employment of retired researchers or engineers: The firm employed or re-employed 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.

In addition to questions asking about these management practices, firms were also asked whether they had innovated new products and/or services in the preceding three years. Table 1 shows the distribution of firms in terms of their answers to these questions. First, in order to obtain a broad overview of the characteristics of management practices at Japanese firms, we look at the number of firms which had implemented at least one practice in each of the three categories, O1, O2, and O3. Table 1 lists various combinations of management practices and shows the number of firms for each combination. The combination (1, 0, 0), for example, represents firms that had implemented at least one of the two practices in category O1 but none of the practices in categories O2 and O3. Similarly, the combination (0, 1, 1) represents firms that had not implemented any of the practices in category O1 but had implemented at least one practice in category O2 and at least one practice in category O3. Further, firms are divided into those that had replied that they had innovated new products and/or services in the preceding three years and those that had not.

As seen in Table 1, the majority of non-innovating firms (55.9%, 1463 firms out of the 2619 non-innovating firms) had not implemented any of the management practices listed in the three categories, i.e., their combination was (0, 0, 0), while most of the innovating firms (83.2%, i.e., 100%–16.8%) had implemented at least one of the management practices listed above. Table 1 thus clearly shows that innovating firms are much more likely to focus on organizational and human resource management for R & D.

That being said, practices in category O1 (cooperation across business units at the firm level) are quite widespread even among non-innovating firms: 1061 (=549 + 363 + 40 + 109) firms out of the 2619 non-innovating firms (40.5%) implement at least one of the practices in category O1, while the corresponding figures for categories O2 and O3 are 561 (=84 + 363 + 5 + 109) and 160 (=6 + 40 + 5 + 109), respectively. Among innovating firms, 969 (=259 + 303 + 67 + 340) out of 1218 firms (80%) implement at least one of the practices in category O1, while 678 (=26 + 303 + 9 + 340) and 425 (=9 + 67 + 9 + 340) firms implement at least one of the practices in categories O2 and O3, respectively. Further, the number of firms implementing practices in the O3 category (restructuring of R & D organization) is much smaller than that of firms implementing practices in the O2 category (human resource management), particularly in the case of non-innovating firms. One possible explanation is that restructuring of R & D organizations may be a less important or more difficult practice than human resource management.

More importantly, a significant number of firms implement practices in more than one category, particularly in the case of innovating firms. 379 firms (31.1%) out of the 1218 innovating firms implement practices in two out of the three categories, and 340 firms (27.9%) implement practices in all three categories, while 294 firms (24.1%) implement practices in only one of the three categories. However, in the case of non-innovating firms, the number and share of firms that implement practices in all three categories is very small: 109 firms or 4.2%. The fact that a substantial share of innovating firms implement all three types of management practices simultaneously suggests that all three categories are potentially important for greater efficiency of R & D activities and that there may be some complementarities among the different management practices.

Table 1
Number of firms implementing different combinations of the three broad categories of organizational and human resource management.

Combinations (O1, O2, O3)	Number of firms (Total = 3837)			
	Product innovation = Yes		Product innovation = No	
	1218	(100.0%)	2619	(100.0%)
None (0, 0, 0)	***205***	***(16.8%)***	***1463***	***(55.9%)***
One	***294***	***(24.1%)***	***639***	***(24.4%)***
(1, 0, 0)	259	(21.3%)	549	(21.0%)
(0, 1, 0)	26	(2.1%)	84	(3.2%)
(0, 0, 1)	9	(0.7%)	6	(0.2%)
Two	***379***	***(31.1%)***	***408***	***(15.6%)***
(1, 1, 0)	303	(24.9%)	363	(13.9%)
(1, 0, 1)	67	(5.5%)	40	(1.5%)
(0, 1, 1)	9	(0.7%)	5	(0.2%)
All (1, 1, 1)	***340***	***(27.9%)***	***109***	***(4.2%)***

4. Complementarities between organizational management and human resource management practices

4.1. Empirical model

Our initial aim is to examine which combinations of management practices determine a firm's innovation success and how large the magnitude of the impact of respective combinations is. Furthermore, we statistically test complementarities among the practices. Specifically, we measure two types of innovation outcomes: product innovation and process innovation. Based on the J-NIS2009 data, we identify whether a firm introduced new or significantly improved products (or production processes) during the preceding three years or not.

We start by estimating a probit model in order to examine what factors determine the probability that a firm introduces new or significantly improved products (or production processes). The probit model assumes that there exists an underlying relationship, $y_i^* = X_i\beta + u_{1i}$, where $u_{1i} \sim N(0,1)$. y_i^* is a latent innovation variable for firm i measuring the propensity to innovate, while X_i is a vector of firm characteristics including the combinations of management practices implemented. The corresponding observed variable, y_i^{probit}, is a binary variable, which takes a value of one for innovators and zero otherwise:

$$y_i^{probit} = (y_i^* > 0) \quad (1)$$

We should note that firms likely decide first whether to invest in R & D activities before they introduce new products or processes. Moreover, firms that do not invest in R & D activities in most cases do not have an official R & D section or department, and are very unlikely to implement any of the management practices regarding R & D organization and R & D human resources. In other words, the estimation results may be biased when the decision of undertaking innovation activities and engaging in R & D management are correlated. We therefore have to take this sample selection into account and consequently employ a probit model with sample selection to address the potential selection bias. More specifically, employing Heckman's (1979) two-step estimation approach, we estimate the determinants of firms' R & D decision in the first stage and then estimate the determinants of innovation success in the second stage. For the first stage estimation regarding whether a firm is engaged in R & D activities, the binary choice variable we use, y_i^{select}, is whether the firm reports positive R & D expenditure for 2006, i.e.:

$$y_i^{select} = (z_i\gamma + u_{2i} > 0) \quad (2)$$

where $u_{2i} \sim N(0,1)$. If ρ (the correlation of u_1 and u_2) $\neq 0$, standard probit techniques yield biased results. As we obtain a statistically significant ρ, we employ the probit model with sample selection.[6] As explanatory variables in the first stage, z_i, we use the logarithm of firms' total sales in 2006 as a proxy for firm size[7] and industry dummies to capture industry-specific factors such as technological characteristics and competitive pressures. We also include various management practice variables and the logarithm of the number of markets in which firms supply their products and/or services as a proxy for the range of their activities. Distinguishing 10 regions around the world, including Japan, the J-NIS 2009 asked in which regions firms sell their products and/or services, and we use this information to count the number of markets (i.e., regions) for each firm. For identification, we exclude firms' total sales in the second-stage probit model. However, it should be noted that our analysis does not allow us to rigorously examine the causal relationship. The reason is that firms may be more likely to implement various management practices if they are undertaking R & D activities that are certain to bring forth new products than if this were not the case. We cannot rigorously address the endogeneity between the decision to implement management practices and the probability of innovation success, since our data are not panel data and we cannot control for unobserved firm-specific factors which affect the certainty of new product development. As described in Section 5 below, we tried some instrumental variables, but found it very difficult to find effective firm-level instruments. Therefore, we mainly rely on the Heckman-type probit model with sample selection without instrumental variables. While this is a limitation of this study, we can examine the direction and strength of the relationship between management practices and innovation success. However, it should be noted that throughout this study we mainly focus on the positive or negative association between management practices and innovation outcomes and do not test rigorously for causal relationships or effects.

We estimate selection Eq. (2) with all observations. We calculate the inverse Mills ratio using Eq. (2) and then estimate Eq. (1) with the restricted observations including the estimated inverse Mills ratio. The explanatory variables of main interest to us are the dummy variables representing various combinations of firms' organizational and human resource management practices. The definitions of these variables are the same as those shown in Table 1 and we prepare seven dummy variables representing the same combinations of management practices presented in the table, with firms that employ none of the practices serving as the reference group. As outlined in the hypotheses in Section 2.6, we generally expect all three broad types of management practices (O1, O2, and O3) to be positively linked with both product and process innovation. However, some of the human resource management practices considered in this study – namely, incentive payments and age diversity – may have a negative relationship with innovation. The negative or ambiguous effect of these human resource management practices may weaken the positive effect of the other two types of management practices.

As other explanatory variables, we also include firms' R & D intensity, which is measured as the logarithm of the ratio of R & D expenditure to total sales, the logarithm of number of markets, and industry dummies based on the 18 industries presented in Appendix A Table A1. The reason for including industry dummies is to capture technological opportunity conditions, industry-targeted innovation policies, industry-specific demand growth effects, and structural effects such as the intensity of competition. Appendix A Tables A2 and A3 respectively present descriptive statistics and correlation coefficients for all the variables.

4.2. Results

The results of the probit estimation with sample selection (average marginal effects) for Eq. (1) above are shown in Table 2.[8] Looking at the results, some of the combinations of management practices, namely, combinations (1,1,0), (1,0,1) and (1,1,1), are positively associated with both product and process innovation. In the case of product innovation, marginal effect of combinations of more than one practice tends to be larger than that of just one practice. For example, O1-type management practices do not have a significant effect on product innovation if merely implemented in isolation. However, when a firm implements both O1-type and O2-type management practices at the same time, the marginal effect of the combination (1,1,0) on product innovation is 0.139 and statistically significant, meaning that the probability to innovate a new product is 13.9% points higher than the probability to innovate of a firm which implement none of the management practices, (0,0,0). Comparing the marginal effects of (1,1,0) and (1,1,1), adding O3 practices increases firms' innovation probability by 10.1% point (=24.0–13.9). On the other hand, comparing the marginal effects of (1,0,1) and (1,1,1), adding O2 practices increases firms' innovation probability by 5% points (=24.0–19.0).

The results indicate that in the case of product innovation, implementing all three management practices at the same time has the highest marginal effect, suggesting that implementing different types of management practices is positively associated with innovation success. However, in the case of process innovation, there is no monotonic increase in the magnitude of marginal effects as the number of practices

[6] In fact, we obtained similar results when we restricted our sample to firms with positive R & D expenditure and estimated the second-stage equation only. However, we report the results with sample selection because ρ was significantly different from zero and the inverse Mills ratio was also statistically significant. Taking account of the fact that many firms conduct both product and process innovations simultaneously, we also tried bivariate probit regressions for process and product innovation equations using the restricted sample of firms with positive R & D expenditure. The results were consistent with our main results shown in Table 2.

[7] Information on the number of employees for each firm is not available. The only available information is the number of employees who are engaged in research activities.

[8] The estimated coefficients for the first and second stage estimations are shown in Appendix A Table A4.

Table 2
Marginal effects of management practice combinations on innovation: Product innovation and process innovation.

	Product innovation selection = implement R & D		Process innovation selection = implement R & D	
	dy/dx	s.e.	dy/dx	s.e.
Log (R & D/Sales)	0.020	0.202	−0.342	0.169**
Log (Nb. of markets)	0.087	0.023***	0.067	0.022***
Combi (0,1,0)	0.019	0.084	0.072	0.075
Combi (0,0,1)	−0.064	0.204	0.369	0.196*
Combi (0,1,1)	0.071	0.163	0.007	0.145
Combi (1,0,0)	0.018	0.041	0.247	0.032***
Combi (1,1,0)	0.139	0.037***	0.174	0.033***
Combi (1,0,1)	0.190	0.069***	0.278	0.063***
Combi (1,1,1)	0.240	0.041***	0.259	0.038***
Industry dummies	YES		YES	
Nb. of observations	3837		3837	
Log pseudolikelihood	−2230.06		−2198.53	
Chi^2	195.05***		295.22***	
Wald test (rho = 0)	20.00***		50.58***	

*, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.
Reference group: firms with combination (0, 0, 0).

implemented increases. Comparing the coefficients across the different combinations, adding O2 practices seems to reduce the size of the coefficient, implying that implementing O2 practices may have a negative impact on process innovation. As mentioned above, some types of human resource management practices may have a negative effect on process innovation. The result implies that it is more difficult to identify who contributes to innovation success in the case of process innovation and that large pay differentials among employees may decrease collaboration and hinder process innovation.

Further, we find that the coefficients on the variables for the different combinations are generally larger for process innovation than for product innovation, and in the case of process innovation are (weakly) significant even in cases where only one type of practice is implemented. The results in Table 2 thus suggest that while implementing different types of management practices at the same time is important for product innovation, in the case of process innovation even implementing only O3 or O1 practices already boosts the chances of innovation success.

For the case of product innovation, we also check whether the magnitude of the coefficient is significantly larger the larger the number of practices firms implemented using the Wald test, and the results are shown in Appendix A Table A5. Appendix Table A5 shows the significance level of the difference between the coefficient on the combination shown in the row of the table and the coefficient on the combination shown in the column of the table. The results confirm that the coefficient tends to be significantly larger the larger the number of practices firms implemented.[9]

5. Which management practices matter for innovation success?

5.1. Details on R & D organizational and human resource management practices

So far, we focused on the three broad categories of organizational and human resource management, O1, O2, and O3, and found that such management practices are positively associated with product and process innovation. We also found that implementing different types of management practices at the same time is important for innovation success, particularly for product innovation.

In this section, we look at each management practice in more detail. As outlined in Section 3.2, each of the three management categories, O1, O2, and O3, comprises between two and four detailed management practices. Table 3 shows the number of firms which implemented each of the management practices included in the three categories. Firms are further divided into two groups: firms which successfully innovated new products in the preceding three years and firms which did not. Looking at Table 3, a large number of firms – including non-innovating firms – implemented both of the two practices in category O1 (cooperation across business units). On the other hand, there seems to be a clear difference between innovating firms and non-innovating firms in human resource management (O2). Among innovating firms, the number of firms is relatively evenly distributed across the three practices: personnel assessment reflecting R & D outcomes, incentive payments, and employment or re-employment of retired researchers or engineers. However, among non-innovating firms, employment or re-employment of retired researchers or engineers is much more widespread than other practices, and personnel assessment reflecting R & D outcomes is much less widespread. In contrast, personnel assessment reflecting R & D outcomes is the most widespread O2 practice among innovating firms. Finally, looking at the two practices in category O3 (restructuring of R & D organization), the number of non-innovating firms implementing such practices is much smaller than that implementing practices in categories O1 or O2, while among innovating firms a substantial number of firms implement practices in category O3.

Although unfortunately further detailed information on each practice is not available, these figures imply that there are significant differences in management practices between innovating and non-innovating firms, and that these differences likely determine innovation outcomes at the firm level.

5.2. Econometric methodology and results

In this section, we examine which management practices are associated with the probability that firms innovate and assess the magnitude of the impact. We start by estimating a probit model with sample selection in order to investigate which factors determine the propensity to innovate new products or services and the propensity to innovate new processes. Similar to the estimations in Section 4, we estimate the determinants of firms' R & D decision in the first stage and then estimate the determinants of innovation at the second stage. For the first-stage estimation, we use the same dependent variable as in the first-stage estimations in Section 4, namely, a binary variable which takes one if a firm reports positive R & D expenditure. As explanatory variables, we include the logarithm of firms' total sales in 2006, the logarithm of the number of markets in which the firm supplies its products and/or services, industry dummies, and eight dummy variables representing the management practices listed in Table 3, namely, interdivisional cooperation/teams, interdivisional meetings/systems, board members with an R & D background, personnel assessment reflecting R & D outcomes, incentive payments, employment/re-employment of retired researchers/engineers, creation/relocation/integration of R & D centers, and increased authority for researchers/engineers. For the second-stage estimation, we use the same dependent variable as in the estimations in Section 4, namely, a binary variable which takes one if a firm innovates new products (or processes) and zero otherwise. As explanatory variables, we include firms' R & D intensity as well as the same explanatory variables as in the first stage, but we exclude firms' total sales in the second-stage estimation.

The binary dependent variable – i.e., whether a firm innovates or not – does not indicate how significant new products are in the market in which firms operate. We therefore also employ an alternative measure of innovation outcomes as a dependent variable. Specifically, we

[9] Given that the results above suggest the existence of complementarities between different types of management practices, we also tested for complementarities among O1, O2, and O3 based on the complementarity test suggested by Kodde and Palm (1986). However, we did not find statistically significant complementarities for any pair of the three types of management practices. Nevertheless, our results above imply that product innovation is positively correlated with the number of practices implemented.

Table 3
Number of firms implementing organizational and human resource management practices.

	Number of firms (Total = 3837)			
	Product innovation = Yes		Product innovation = No	
Total number of firms	1218	(100.0%)	2619	(100.0%)
O1) *Cooperation across business units*				
Interdivisional cooperation/teams	770	(63.2%)	677	(25.8%)
Interdivisional meetings/systems	922	(75.7%)	982	(37.5%)
O2) *Human resource management*				
Board members with R & D background	219	(18.0%)	73	(2.8%)
Personnel assessment reflecting R & D outcomes	415	(34.1%)	155	(5.9%)
Incentive payments	386	(31.7%)	222	(8.5%)
Employment or re-employment of retired researchers or engineers	362	(29.7%)	399	(15.2%)
O3) *Restructuring of R & D organaization*				
Creation/relocation/integration of R & D centers	388	(31.9%)	129	(4.9%)
Increased authority for researchers/engineers	117	(9.6%)	54	(2.1%)

Table 4
Marginal effects of management practices on innovation: Product innovation and process innovation.

	Product innovation selection = implement R & D		Process innovation selection = implement R & D	
	dy/dx	s.e.	dy/dx	s.e.
Log (R & D/Sales)	−0.062	0.219	−0.426	0.237*
Log (Nb. of markets)	0.083	0.024***	0.082	0.023***
Interdivisional cooperation/teams	0.092	0.035***	0.131	0.031***
Interdivisional meetings/systems	0.001	0.037	0.105	0.032***
Board members with R & D background	0.089	0.047*	0.007	0.043
Personnel assessment reflecting R & D outcome	0.150	0.037***	0.051	0.037
Incentive payment	−0.046	0.037	−0.094	0.035***
Employment or re-employment of retired researchers or engineers	−0.043	0.035	−0.028	0.033
Creation/relocation/integration of R & D centers	0.112	0.037***	0.065	0.036*
Increased authority for researchers/engineers	−0.026	0.052	0.078	0.051
Industry dummies	YES		YES	
Nb. of observations	3837		3837	
Log pseudolikelihood	−2192.91		−2433.4	
Chi^2	209.94***		307.05***	
Wald test (rho = 0)	21.80***		45.16***	

Significant * at 10%, ** at 5%, *** at 1%.

Table 5
Marginal effects based on interval regression.

	Catch-up time	
	dy/dx	s.e.
Log (R & D/Sales)	−0.458	0.333
Log Sales (2006)	0.046	0.043
Log (Nb. of markets)	−0.345	0.111***
Interdivisional cooperation/teams	0.317	0.157**
Interdivisional meetings/systems	−0.257	0.197
Board members with R & D background	0.368	0.179**
Personnel assessment R & D outcome	0.469	0.147***
Incentive payment	−0.083	0.156
Employment or re-employment of retired researchers or engineers	0.061	0.163
Creation/relocation/integration of R & D centers	0.249	0.142*
Increased authority for researchers/engineers	0.097	0.190
Industry dummies	YES	
Nb. of observations	1218	
Wald chi^2	120.53***	

Significant * at 10%, ** at 5%, *** at 1%.

construct a variable representing the technological superiority of a new products using information on the time a firm thinks it would take competitors to catch up with its most important innovative product.

In the J-NIS 2009, firms were asked to choose one of the following six answers regarding how long it would take competitors to invent a similar product: (1) less than 6 months; (2) 6 months to 1 year; (3) 1–3 years; (4) 3–5 years; (5) 5–10 years; and (6) more than 10 years. The more superior a new product or service innovation is, the longer it will take competitors to catch up, so that we use the answers to this question to indicate how significant a product innovation is.

Only firms that innovated new products were asked this question on how long it would take competitors to catch up. In the analysis using this alternative measure of innovation outcome as the dependent variable we therefore restrict our sample to firms that achieved product innovation. More specifically, we conduct an interval regression with the 1218 innovating firms in our sample. Interval regression fits a model in which the dependent variable may be measured as point data, interval data, left-censored data, or right-censored data. We therefore create a dependent variable containing the lower and upper endpoints of the above 6 choices. Doing so, we end up with 227 left-censored observations (firms responding that the expected catch-up time was equal to or less than 6 months), 22 right-censored observations (firms responding that the expected catch-up time was equal to or more than 10 years), and 969 interval observations.

We first present the results of the probit estimation which examines the factors determining whether firms innovate or not (Table 4). Then, in the latter half of this section, we present the results of the interval regression taking account of the technological superiority of a new product (Table 5). Table 4 shows the results of the probit estimation with sample selection (average marginal effects).[10] While some of the organizational and human resource management practices are associated with both product and process innovation, others are associated with product or process innovation only. Specifically, interdivisional cooperation/teams, and creation/relocation/integration of R & D centers are positively associated with both product and process innovation. Interdivisional meetings/systems is positively associated with process innovation only. On the other hand, having board members with an R & D background and personnel assessment reflecting R & D outcomes are positively associated with product innovation only, while incentive payments are negatively associated with process innovation only.

While interdivisional cooperation/teams and interdivisional meetings/systems have a higher marginal effect than personnel assessment and restructuring of R & D centers in the case of process innovation, the opposite is observed in the case of product innovation. These results suggest that horizontal communication across divisions and teamwork are more important for process innovation. On the other hand, board members with an R & D background, personnel assessment, and drastic changes in R & D organization are more important for product innovation, implying that top-down R & D decision-making may have a larger impact on product innovation. In fact, in the case of product innovation, the marginal effect of having a board member with an R & D background is 0.089, implying that assigning a person with an R & D background as a board member increases the probability of innovating new products by 8.9% points. Given the fact that the share of product innovators in the total sample is 31.7% (=1218/3837; see Table 1 or 3), this is a significant increase in the probability.

In line with the results in Table 2, the results in Table 4 suggest that human resource (O2-type) management practices do not have any positive and significant impact on process innovation. In fact, incentive payment schemes – one of the human resource management practices – even seems to be negatively associated with process innovation, suggesting that pay differentials hinder collaboration among employees and process innovation. On the other hand, the results in Table 4 show that interdivisional cooperation and meetings are particularly important for process innovation.

As for product innovation, all three types of management practices (O1–O3) are important, which is consistent with the results in Table 2. More importantly, however, the positive association between board members with an R & D background and the creation/relocation/integration of R & D centers on the one hand and product innovation on the other suggests that top-down R & D decision making and selective resource allocation increase the propensity to innovate. That is, such practices possibly reflect and/or engender the active management of a firm's innovation portfolio. This result is in line with Klingebiel and Rammer's (2014) argument that firms' innovation portfolio management and allocation of innovation resources are potentially important determinants of their innovation performance. Moreover, the creation/relocation/integration of R & D centers may also promote interdivisional communication. Because new product development and innovation require the application and combination of specialized knowledge inputs from many different areas (Yli-Renko et al., 2001), these two practices potentially reinforce each other and raise the propensity to innovate.

On the other hand, there is no significant association between the employment or re-employment of retired researchers or engineers and either type of innovation, and the coefficient estimate is even negative. As mentioned in Section 2.2, employee diversity can have both positive and negative effects on innovation performance. The insignificant results in our study suggest that the positive and negative effects cancel each other out.

Next, turning to the role of authority for researchers or engineers, the results indicate that such authority has no significant impact on both product and process innovation. On the other hand, incentive payments are negatively associated with process innovation, while no statistically significant effect is observed in the case of product innovation. As mentioned in Section 2, previous studies tend to suggest that intrinsic motivation (i.e., individuals' enthusiasm for science) is more important for researchers' performance than extrinsic motivation through, e.g., financial incentives.[11] Our finding of a negative relationship between incentive payments and process innovation is in line with those studies; on the other hand, the reasons for the insignificant result in the case of product innovation deserves further investigation in the future. Meanwhile, personnel assessment reflecting R & D outcomes has a significantly positive marginal effect on product innovation, raising the probability of introducing new products by 15.0% points. A possible interpretation of these results is that financial incentives may be counterproductive in fostering an environment that stimulates process innovation, while personnel assessment either offers incentives to innovate new products/services – for example, by providing recognition – or helps to identify the most innovative R & D personnel.[12]

The results of the interval regression are presented in Table 5. They show that four types of management practices have a significantly positive impact in terms of generating significant product innovations (where the significance of innovations is gauged based on the time firms expect it will take rivals to catch up): interdivisional cooperation/teams, having board members with an R & D background, personnel assessment reflecting R & D outcomes, and the creation/relocation/integration of R & D centers. Both in Tables 4 and 5, these practices have a significant and relatively large positive marginal effect. Therefore, all our results suggest that among the various management practices, these four practices are important for achieving product innovations, particularly significant innovations that take longer to replicate (referred to as "breakthrough innovations" hereafter). It is interesting to note that the use of interdivisional cooperation/teams is a practice in category O1, while having board members with an R & D background and relying on personnel assessment reflecting R & D outcome

[10] The estimated coefficients for the first- and second-stage estimations are shown in Appendix A Table A6. We also estimated the same probit model with sample selection but without some explanatory variables that are highly correlated with other explanatory variables. However, the results were similar to those in Table 4 and are therefore not shown. (They are available from the authors on request.) Moreover, as in Section 4, we restricted our sample to firms with positive R & D expenditure and estimated the second-stage equation only. We also tried bivariate probit regressions for the process and product innovation equations using the restricted sample of firms with positive R & D expenditure. Again, the results were similar to those in Table 4. Given that firm-level R & D intensity potentially is an endogenous variable, we also tried IV probit estimation. For the instrumental variable, we constructed a binary variable representing the degree of competition in the market. Specifically, the variable takes a value of one if a firm answered in the J-NIS questionnaire that its products/services became more diversified or the lifecycle of its products/services became shorter, and zero otherwise. In addition, we constructed a range of other instrumental variables. However, the test of overidentifying restrictions indicated that our instrumental variables were likely to be correlated with the error term when we used two instrumental variables. Thus, it was extremely difficult to find good and effective instrumental variables, given that firm-level financial or performance information other than R & D-related information is quite limited in our data and our dataset is not a panel but a cross section. Therefore, we only show the IV probit estimation results using the binary variable representing the degree of competition in the market as an instrument in Appendix A Table A7. As can be seen, the results are broadly consistent with those in Table 4.

[11] Although there are an increasing number of theoretical and experimental studies by psychologists, sociologists, and economists on researchers' intrinsic and extrinsic motivation (e.g., Bénabou and Tirole 2003; Manso 2011), systematic empirical studies using real-world data are extremely scarce. One of the few exceptions is the study by Owan and Nagaoka (2011), who examine the relationship between the strength of inventors' intrinsic and extrinsic motivation and their productivity (proxied by patent applications) using large-scale survey data of Japanese inventors.

[12] Kanama and Nishikawa (2017), using the same dataset as our study, find that performance-based evaluation promotes innovation, while monetary compensation does not, which is consistent with our results.

are practices in category O2, and the creation/relocation/integration of R & D centers is a practice in category O3. This implies that both organizational and human resource management significantly affect firms' innovation outcomes. As for human resource management of R & D personnel, while personnel assessment reflecting R & D outcomes has a large positive marginal effect in terms of achieving breakthrough innovations, incentive payments and the employment or re-employment of retired researchers or engineers do not have a significant impact in terms of achieving significant innovations.

Moreover, having board members with an R & D background and the creation/relocation/integration of R & D centers have a significant positive marginal effect, which is consistent with the results on product innovation in Table 4 and implies that drastic top-down decision-making seems to foster breakthrough innovation.

6. Conclusion

In this study, we examined the link between firms' organizational and human resource management of their research units on the one hand and innovation outcomes on the other. Our findings can be summarized as follows. First, implementing more than one management practice at the same time is associated with a higher probability of innovating new products. Our results suggest that implementing different types of organizational and human resource management practices at the same time significantly raises the probability of product innovation. However, in the case of process innovation, the magnitude of the marginal effects does not monotonically increase in the number of practices implemented: the human resource management practices considered in this paper do not necessarily raise the probability of process innovation when they are implemented together with other organizational management practices.

Second, particularly for product innovation, we found that four types of management practices – namely, the use of interdivisional cooperation/teams, having board members with an R & D background, personnel assessment reflecting R & D outcomes, and the creation/relocation/integration of R & D centers – are positively associated with innovation success. The results were very similar when we focused on breakthrough innovation, i.e., taking the technological superiority of products into account.

The results suggest that human resource management of R & D personnel is an important determinant of innovation success and that providing the right incentives to motivate researchers and assessing researchers are important for promoting breakthrough innovation.

Our results also suggest that having board members with an R & D background and the creation/relocation/integration of R & D centers are important for product innovation. Top-down R & D decision-making and drastic organizational changes may serve as clear signals of a firm's determination to pursue an innovation-oriented strategy and help to accelerate innovation success. Moreover, these practices may help firms to allocate innovation resources effectively and promote interdivisional communication or communication with external information sources. Shiseido, a global cosmetics company headquartered in Japan, provides an example: in 2015, the company announced a plan to reform its R & D organization and establish one of the world's largest cosmetics research facilities in the city of Yokohama (The Nikkei, March 27, 2015). According to the announcement, Shiseido was planning to adopt an open lab where customers, marketers, and researchers mingle on a daily basis. The expectation was that such an environment would strengthen basic research as well as research in new fields. Shiseido's case thus provides a concrete example of a firm restructuring its R & D organization in order to create an environment in which researchers can easily communicate with workers in other divisions and/or even outsiders.

It is often argued that generating value from innovation has been getting much harder in the past few decades, especially for many Japanese firms that have had to contend with a long period of economic stagnation during the so-called "two lost decades." For example, the Cabinet Office of the Government of Japan (2011) reports that the effectiveness of R & D (i.e., the ratio of value added generated by the private sector to R & D expenditure calculated using the country-level R & D data taken from OECD.stat) has been declining in many developed economies, with the decline particularly pronounced in Japan. Our findings provide a clue as to how the effectiveness of R & D could be boosted, for instance by implementing personnel assessment not in isolation but in combination with a system of knowledge sharing among researchers and workers. Our results also suggest that having board members with an R & D background and the restructuring of R & D centers can help to allocate resources effectively and create an environment in which knowledge sharing is promoted, boosting the likelihood of successful product innovation.

Given various data limitations, however, these results should be interpreted with caution. For example, our data contain no detailed information on the assessment and/or payment system each firm employs. The effects of the pay-for-performance system may depend on the relative importance of incentive payments compared to fixed payments. Similarly, the effects of personnel assessment may depend on the importance of research outcomes in personnel assessments, that is, the extent to which research outcomes are taken into account in personnel assessments and/or the promotion of researchers. Moreover, whether or not, or to what extent, researchers' wages reflect the result of personnel assessment may affect their motivation and change the rate and direction of innovation. Due to data constraints, however, we cannot control for the relative importance of incentive payments and personnel assessment or the potential links between them. Moreover, we also do not know details on R & D organizational changes, that is, whether an R & D center was created, relocated, or integrated. To understand the relationship between organizational structure and innovation success, it would be necessary to combine quantitative analyses such as those in this study with detailed case studies.

Last but not least, as mentioned above, data limitations mean that we cannot rigorously examine the causal relationship between management practices and innovation success. In order to examine causal relationships and the mechanisms underlying such relationships, we would need to construct firm-level panel data and/or utilize various data sources for detailed firm-level information. Although data constraints mean that this is not an easy task, we believe that future studies which address these issues would provide further insights to gain a better understanding of firms' innovation and the role of organizational and human resource management.

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Appendix A

Table A1
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 plant 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 plastic products	25	102
Other non-metallic 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
Non-manufacturing		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 and storage; 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

Table A2
Descriptive statistics.

Variables	Number of observations	Mean	Std. Dev.	Min	Max
Innovation outputs					
Product innovation	3837	0.317	0.466	0	1
Process innovation	3837	0.571	0.495	0	1
Catch-up time	1218	2.716	2.145	0.5	10
Explanatory variables					
Log (R & D/Sales)	3837	0.006	0.039	0.000	1.684
Log Sales (2006)	3837	7.919	1.946	0.000	16.203
Log (Nb. of markets)	3837	0.784	0.517	0.000	2.398
O1) *Coorperation across business units*					
Interdivisional cooperation/teams	3837	0.377	0.485	0	1
Interdivisional meetings/systems	3837	0.496	0.500	0	1
O2) *Human resource management*					
Board members with R & D background	3837	0.076	0.265	0	1
Personnel assessment reflecting R & D outcome	3837	0.149	0.356	0	1
Incentive payment	3837	0.158	0.365	0	1
Employment or re-employment of retired researchers or engineers	3837	0.198	0.399	0	1
O3) *Restructuring R & D organization*					
Creation/relocation/integration of R & D centers	3837	0.135	0.341	0	1
Increased authority for researchers/engineers	3837	0.045	0.206	0	1
Combination (O1, O2, O3)					
Combi (0,1,0)	3837	0.029	0.167	0	1
Combi (0,0,1)	3837	0.004	0.062	0	1
Combi (0,1,1)	3837	0.004	0.060	0	1
Combi (1,0,0)	3837	0.211	0.408	0	1
Combi (1,1,0)	3837	0.174	0.379	0	1
Combi (1,0,1)	3837	0.028	0.165	0	1
Combi (1,1,1)	3837	0.117	0.321	0	1

Table A3
Correlation coefficient matrices.

Panel (a): Variables used for the Heckman probit model estimations (Tables 2 and 4: 3837 observations)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1) Product innovation	1.000																			
(2) Process innovation	0.408	1.000																		
(3) Log (& D/Sales)	0.107	0.061	1.000																	
(4) Log Sales (2006)	0.274	0.230	0.023	1.000																
(5) Log (Nb. of markets)	0.329	0.302	0.115	0.334	1.000															
(6) Combi (0,1,0)	−0.030	0.001	−0.002	−0.055	−0.011	1.000														
(7) Combi (0,0,1)	0.038	0.027	0.001	−0.001	0.011	−0.011	1.000													
(8) Combi (0,1,1)	0.042	0.023	0.000	0.010	0.026	−0.010	−0.004	1.000												
(9) Combi (1,0,0)	0.003	0.084	0.006	0.003	−0.019	−0.089	−0.032	−0.031	1.000											
(10) Combi (1,1,0)	0.135	0.167	0.027	0.095	0.137	−0.079	−0.029	−0.028	−0.237	1.000										
(11) Combi (1,0,1)	0.112	0.103	0.009	0.063	0.053	−0.029	−0.011	−0.010	−0.088	−0.078	1.000									
(12) Combi (1,1,1)	0.344	0.286	0.115	0.252	0.320	−0.063	−0.023	−0.022	−0.188	−0.167	−0.062	1.000								
(13) Interdivisional cooperation/teams	0.359	0.382	0.103	0.299	0.289	−0.134	−0.049	−0.047	0.267	0.306	0.133	0.373	1.000							
(14) Interdivisional meetings/systems	0.356	0.397	0.084	0.259	0.305	−0.171	−0.062	−0.060	0.435	0.416	0.142	0.339	0.649	1.000						
(15) Board members with R & D background	0.267	0.197	0.123	0.231	0.291	0.016	−0.018	0.032	−0.148	0.151	−0.049	0.412	0.270	0.246	1.000					
(16) Personnel assessment R & D outcome	0.369	0.303	0.132	0.257	0.338	−0.019	−0.026	0.036	−0.216	0.285	−0.071	0.548	0.371	0.380	0.422	1.000				
(17) Incentive payment	0.296	0.250	0.106	0.292	0.326	0.045	−0.027	0.045	−0.224	0.378	−0.074	0.437	0.335	0.362	0.365	0.495	1.000			
(18) Employment or re-employment of retired researchers or engineers	0.169	0.216	0.052	0.135	0.238	0.244	−0.031	0.111	−0.257	0.473	−0.084	0.344	0.302	0.340	0.274	0.311	0.344	1.000		
(19) Creation/relocation/integration of R & D centers	0.367	0.299	0.111	0.284	0.318	−0.068	0.134	0.141	−0.204	−0.181	0.350	0.809	0.359	0.327	0.365	0.440	0.362	0.261	1.000	
(20) Increased authority for researchers or engineers	0.170	0.165	0.066	0.051	0.128	−0.037	0.088	0.050	−0.112	−0.099	0.186	0.448	0.194	0.177	0.148	0.265	0.166	0.171	0.296	1.000

Panel (b): Variables used for the interval regression (Table 5: 1218 observations)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Catch-up time	1.000											
(2) Log of R & D/sales	0.007	1.000										
(3) Log of sales (2006)	0.052	−0.041	1.000									
(4) Log (nb.of markets)	−0.064	−0.020	0.054	1.000								
(5) Interdivisional cooperation/teams	0.125	0.056	0.244	−0.012	1.000							
(6) Interdivisional meetings/systems	0.081	0.008	0.205	-0.030	0.558	1.000						
(7) Board members with R & D background	0.141	0.078	0.258	−0.038	0.210	0.186	1.000					
(8) Personnel assessment R & D outcome	0.220	0.107	0.222	−0.033	0.316	0.329	0.356	1.000				
(9) Incentive payment	0.100	0.080	0.304	−0.015	0.248	0.288	0.336	0.437	1.000			
(10) Employment or re-employment of retired researchers or engineers	0.107	0.031	0.182	−0.075	0.248	0.246	0.287	0.289	0.342	1.000		
(11) Creation/relocation/integration of R & D centers	0.158	0.051	0.253	−0.029	0.291	0.264	0.315	0.400	0.298	0.229	1.000	
(12) Increased authority for researchers/engineers	0.094	0.027	−0.008	−0.030	0.145	0.119	0.076	0.199	0.087	0.159	0.255	1.000

Table A4
Estimated coefficients for the Heckman probit model: Management practice combinations.

	Product innovation selection = implement R & D		Process innovation selection = implement R & D	
	coeff.	s.e.	coeff.	s.e.
Log (R & D/Sales)	0.057	0.559	−1.044	0.518**
Log (Nb. of markets)	0.242	0.066***	0.204	0.069***
Combi (0,1,0)	0.053	0.232	0.221	0.229
Combi (0,0,1)	−0.177	0.565	1.126	0.600*
Combi (0,1,1)	0.197	0.453	0.021	0.444
Combi (1,0,0)	0.049	0.115	0.754	0.109***
Combi (1,1,0)	0.386	0.106***	0.532	0.102***
Combi (1,0,1)	0.526	0.193***	0.850	0.195***
Combi (1,1,1)	0.666	0.115***	0.791	0.117***
Selection equation (Dependent variable:Implement R & D)				
Log Sales (2006)	0.063	0.015***	0.062	0.015***
Log (Nb. of markets)	0.439	0.054***	0.431	0.054***
Combi (0,1,0)	0.670	0.145***	0.661	0.146***
Combi (0,0,1)	0.844	0.402**	0.831	0.401***
Combi (0,1,1)	1.083	0.337***	1.063	0.338***
Combi (1,0,0)	0.724	0.071***	0.718	0.071***
Combi (1,1,0)	0.955	0.071***	0.946	0.071***
Combi (1,0,1)	1.252	0.138***	1.242	0.137***
Combi (1,1,1)	1.363	0.087***	1.350	0.087***
Inverse mills ratio	0.116	0.019***	0.059	0.019***
Industry dummies	YES		YES	
Nb. of observations	3837		3837	
Log pseudolikelihood	−2230.06		−2198.53	
Chi^2	195.05***		295.22***	
Wald test (rho = 0)	20.00***		50.58***	

*, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.
Reference group: firms with combination (0,0,0).

Table A5
Chi-square test on the weight of pairs of combinations: Product innovation.

	(1,0,0)	(0,1,0)	(0,0,1)	(1,0,1)	(1,1,0)	(0,1,1)	(1,1,1)
(1,0,0)	n.a.			**	***		***
(0,1,0)	n.a.	n.a.		*			***
(0,0,1)	n.a.	n.a.	n.a.				
(1,0,1)	n.a.	n.a.	n.a.	n.a.			
(1,1,0)	n.a.	n.a.	n.a.	n.a.	n.a.		**
(0,1,1)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
(1,1,1)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

*, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.
n.a.: Not applicable.

Table A6
Estimated coefficients for the Heckman probit model: Management practices

	Product innovation selection = implement R & D		Process innovation selection = implement R & D	
	coeff.	s.e.	coeff.	s.e.
Log (R & D/Sales)	−0.173	0.608	−1.264	0.704
Log (Nb. of markets)	0.231	0.069***	0.244	0.071***
Interdivisional cooperation/teams	0.254	0.097***	0.389	0.094***
Interdivisional meetings/systems	0.003	0.102	0.311	0.098***
Board members with R & D background	0.248	0.131*	0.021	0.128
Personnel assessment reflecting R & D outcome	0.416	0.102***	0.152	0.108
Incentive payment	−0.129	0.103	−0.280	0.106***
Employment or re-employment of retired researchers or engineers	−0.119	0.097	−0.084	0.099
Creation/relocation/integration of R & D centers	0.312	0.103***	0.194	0.106*
Increased authority for researchers/engineers	−0.073	0.144	0.233	0.151
Selection equation (Dependent variable: Implementing R & D)				
Log Sales (2006)	0.044	0.015***	0.044	0.015***
Log (Nb. of markets)	0.417	0.055***	0.408	0.055***
Interdivisional cooperation/teams	0.115	0.067*	0.115	0.067*
Interdivisional meetings/systems	0.542	0.068***	0.539	0.068***

(*continued on next page*)

Table A6 (*continued*)

	Product innovation selection = implement R & D		Process innovation selection = implement R & D	
	coeff.	s.e.	coeff.	s.e.
Board members with R & D background	−0.068	0.107	−0.078	0.106
Personnel assessment reflecting R & D outcome	0.502	0.080***	0.498	0.080***
Incentive payment	0.310	0.076***	0.305	0.076***
Employment or re-employment of retired researchers or engineers	−0.105	0.068	−0.101	0.068
Creation/relocation/integration of R & D centers	0.257	0.081***	0.258	0.081***
Increased authority for researchers/engineers	0.409	0.132***	0.397	0.130***
Inverse mills ratio	0.141	0.017***	0.108	0.018***
Industry dummies	YES		YES	
Nb. of observations	3837		3837	
Log pseudolikelihood	−2192.91		−2170.07	
Chiˆ2	209.94***		275.90***	
Wald test (rho = 0)	21.80***		40.26***	

*, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

Table A7
Estimated marginal effects: IV probit model.

	IV: firms with frequent product/service differentiation			
	Product innovation		Process innovation	
	coeff.	s.e.	coeff.	s.e.
Log (R & D/Sales)	−38.536	29.771	−131.668	74.084*
Log Sales (2006)	0.035	0.038	−0.090	0.095
Log (Nb. of markets)	0.516	0.156***	0.854	0.386**
Interdivisional cooperation/teams	0.452	0.156***	0.975	0.392**
Interdivisional meetings/systems	0.362	0.093***	0.476	0.234**
Board members with R & D background	0.577	0.298	1.027	0.744
Personnel assessment reflecting R & D outcome	0.664	0.206***	0.977	0.517*
Incentive payment	0.213	0.147	0.342	0.372
Employment or re-employment of retired researchers or engineers	−0.283	0.121**	−0.280	0.304
Creation/relocation/integration of R & D centers	0.677	0.152***	0.762	0.384**
Increased authority for researchers/engineers	0.304	0.195	0.690	0.493
Industry dummies	YES		YES	
Nb. of observations	3837		3837	
Wald chiˆ2	499.23		93.16	
Wald test of exogeneity	3.67*		42.98***	

Endogenous variable = Log (R & D/sales)
IV: A dummy variable which takes one for firms that answered that products/services became more diversified or the lifecycle of products/services shorter
*, **, and *** indicate significance at the 10%, 5%, and 1% level, respectively.

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